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GUIDELINES ON DESIGN AND INSTALLATION OF NOISE BARRIERS FOR ROADS

INDIAN ROADS CONGRESS
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ABBREVIATIONS/ NOTATIONS/ SYMBOLS

CPCB	Central Pollution Control Board
dB	Decibels
dB (A)	A-Weighted sound levels in decibels
DL_{α}	Single number rating of sound absorption performance expressed as a difference of A weighted sound pressure levels, in decibels
$DL_{\alpha NRD}$	Single number rating of sound absorption performance expressed as a difference of A weighted sound pressure levels (in dB)
DL_{R}	Single-number rating of airborne sound insulation performance, expressed as the difference between A weighted sound pressure levels, in decibels.
SI	Sound Insulation Index [in dB]. This is a measure for the ratio of the energy transmitted by the noise barrier and the energy incident on the noise barrier, averaged over j^{th} one third octave frequency band
DLSI,P	Single number quantity for the Sound Insulation Index SI [in dB], defined for Posts (P)
DLSI,E	Single number quantity for the Sound Insulation Index SI [in dB], defined for Acoustic Element (E)
DLSI,G	DLSI, G – Global Single number rating for Sound Insulation Index SI [in dB]
DLRI	Single number rating of Sound Reflection (dB)
EI	Educational Institution
EPDM	Ethylene Propylene Diene Monomer
FHWA	Federal Highway Administration (of USA)
HI	Health Institution
H1/H2	High Containment Level-1/ High Containment Level-2 as per EN-1317-2
IRC	Indian Roads Congress
IFC	International Finance Corporation
L_{eq}	L- equivalent is energy mean of noise level over a period of time
MoEFCC	Ministry of Environment, Forest & Climate Change
MoRTH	Ministry of Road Transport and Highways
MASH	Manual for Assessing Safety Hardware (American)
PMMA	Poly Methyl Meta Acrylate
PVB	Polyvinyl Butyral
PVC	Polyvinyl Chloride
STAAD	Structural Analysis and Design Software
TRL	Transport Research Laboratory (of UK)
TL	Transmission Loss
IL	Insertion Loss
IS	Indian Standard

UNITS OF MEASURE

kg/m^3	Kilogram per cubic meter
kg/m^2 or kg/sqm	Kilogram per square meter
Kn	Kilonewton
m	Meter
MPa	Megapascal
µPa	Micropascal
mm	Millimetre
N/mm^2	Newton per square millimetre

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GUIDELINES ON DESIGN AND INSTALLATION OF NOISE BARRIERS FOR ROADS

INTRODUCTION

A by- product of India's vast road network and ever-increasing vehicular traffic is noise pollution in both urban and rural areas. Increasing density of populated areas along the roads and highways is also a major factor, prioritizing the need to attenuate road noise. Various sources of road noise are pavement- tyre friction, vehicle engines and vehicle horns. Continuous exposure to noise beyond permissible limit tends to have both psychological and physiological ill-effects. These ill effects can be attenuated using a Noise Barrier. Noise barriers are a structure, or structure together with other material, that potentially alters the noise level at a site from a BEFORE condition to an AFTER condition. Basically, it is designed to protect inhabitants of sensitive land use areas from noise pollution. The aspect of noise attenuation has been also flagged in the Guidelines on Preparation and Implementation of Environment Management Plan published by IRC as IRC:SP:108 and in the Guidelines for Green Rating of Highways as IRC:SP:122. The Commmitte on Reduction of Carbon Footprints in Road Contruction and Environment (G-3) in its meeting held on 20th April, 2018 entrusted the task of preparation of initial draft to the Sub-Group under the chairperson, Dr. Anuradha Shukla, Chief Scientist and Head, Environment Division, CRRI with other members; Shri D.P. Gupta, Ms. Tamosi Bhattacharya, Ms. Neha Vyas, Dr. Ankit Gupta, Shri Bharat Anand and Shri Shashank Narain. The Sub-Group met several times including online meetings hosted by Shri Bharat Anand. The Sub-Group also benefited from the discussions and inputs received from the various experts from National and International Industry and Research Institutes namely Dr. Naresh, Tandon, Shri Vinay Dubey, Shri Cesar Fernandes, Shri Giovanni Cucco and Shri Tamir Lavi during the preparation of the draft guidelines. The initial draft so prepared was submitted to the main G-3 Committee. The valuable contribution made by each and every member of the Sub-Group is gratefully acknowledged.

These guidelines have been framed to standardize the criteria considered for choosing sensitive locations, design and installation of noise barrier that can be easily followed by the EIA/DPR Consultants and Contractors. This will help in estimating the dimensions and specifications of proposed noise barrier that in turn will lead to estimation of cost likely to be incurred at implementation stage. Estimation of cost during tendering will leave both the Executing Agency and Contractor at a better position to abide by the Contractual Agreement in terms of noise barriers.

Various International Guidelines have been referred to while preparing these guidelines and finalized after a rigorous and critical review by the Honorable members of Committee on Reduction of Carbon Footprints in Road Construction and Environment (G-3) in a number of meetings. Gaps, if any, in these guidelines will be duly filled in due course of time based on experience and further enrichment of literature. During the 11th meeting of the G-3 Committee held on 11th July, 2020, the draft of the Guidelines was approved for submission to the GSS Committee.

The General Specifications & Standards Committee (GSS) considered and approved the draft guidelines in its meeting held on 19th November, 2020 for placing it before Executive Committee and IRC Council. The Executive Committee in its meeting held on 18th February, 2021 considered and approved the same for placing it before the Council. The IRC council in its 221st Council Meeting

held at New Delhi on 20th February, 2021 considered and approved the "Guidelines on Design and Installation of Noise Barriers for Roads" for printing.

The Indian Roads Congress would therefore, welcome suggestions and feedback from users so that any further modification/updating may be incorporated in due course.

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1. SCOPE

These Guidelines on Noise Barriers cover abatement of noise generated by movement of vehicles on roads in both urban and rural areas. Regulations relating to permissible noise levels as prescribed by the Central Pollution Control Board for different land-use, residential, commercial, hospitals etc. are given. These Guidelines cover the warrants as to where and in which situations, noise barriers would be required for abatement of noise and design aspects

such as length, height, placement, colors, patterns and aesthetics are brought out along with various types of barriers and their material properties and specifications.

Procedures for installation, regular inspection and maintenance arrangements are also described briefly. These are critical to ensure effective abatement of noise on sustainable basis. The Road Authorities would need to keep in view the instructions of the fabricators of these barriers.

Further,the vegetation barriers are described in this document. In any case, they would depend on the natural vegetation and environmental conditions in the area where these are to be provided.

These guidelines exclude the treatment measures to reduce noise on road pavements.It may also be noted that all photographs given in this guidelines are representative only. Each Manufacturer may have their own unique design.The Manufacturers shall produce test reports from accredited laboratories for both acoustic and non-acoustic performance criteria.

Terminologies

Decibel (dB) — A unit of measure of sound level. The number of decibels is calculated as ten times the base-10 logarithm of the square of the ratio of the mean-square sound pressure (often referred to as frequency weighted), and the reference mean-square sound pressure of 20 μPa, the threshold of human hearing.

A- Weighted (dB(A) — It is an expression of the relative loudness of sound in air as perceived by the human ear. The A-weighting network de-emphasizes the high (6.3 kHz and above) and low (below 1 kHz) frequencies, and emphasizes the frequencies between 1kHz and 6.3 kHz, in an effort to simulate the relative response of the human ear.

Divergence — The spreading of sound waves from a source in a free field environment. In the case of highway traffic noise, two types of divergence are common, spherical and cylindrical. Spherical divergence is that which would occur for sound emanating from a point source, e.g., a single vehicle pass-by. Cylindrical divergence is that which would occur for sound emanating from a line source, or many point sources sufficiently close to behave as a line source, e.g., a continuous stream of roadway traffic.

Degradation — The increase in noise levels at receivers due to conditions such as reflections from a single barrier, multiple reflections of the noise between parallel barriers, noise leaks in a barrier, etc

Diffracted Wave — A sound wave whose front has been changed in direction by an obstacle in the propagation medium, where the medium is air for the purposes of these gudlines.

Frequency — The number of cycles of repetition per second or the number of wavelengths that have passed by a stationary point in one second

Gabion	A wire mesh basket filled with stones or broken concrete which forms part of a larger unit used for slope stability, erosion control, or other purposes such as noise barrier walls.
Insertion Loss (IL)	The sound level at a given receiver before the construction of a barrier minus the sound level at the same receiver after the construction o the barrier. The construction of a noise barrier usally results in a partial loss of soft-ground attenuation. This is due to the barrier forcing the sound to take a higher path relative to the ground plane. Therefore, barrier IL is the net effect of barrier diffraction, combined with this partial loss of soft-ground attenuation.
Line-of-Sight	Refers to the direct path from the source to receiver without any intervening objects or topography.
Noise	Any unwanted sound. "Noise" and "sound" are used interchangeably in this document.
Noise Barrier	The structure, or structure together with other material, that potentially alters the noise at a site from a BEFORE condition to an AFTER condition
Sound Absorption	Sabine Absorption Coefficient (SAB)- Absorption coefficient obtained in a reverberation room by measuring the time rate of decay of the sound energy density with and without a patch of the sound-absorbing material under test laid on the floor. These measurements are performed in accordance with the American Society of Testing and Materials (ASTM) Standard C 423-90a.
Sound Insulation	It is the ability of a structure/ barrier to reduce sound transmission and is measured over a range of frequencies.
Sound Energy	Commonly referred to as the mean-square sound-pressure ratio, sound energy, or just plain energy, acoustic energy is the square of the ratio of the mean-square sound pressure and the reference mean squared sound pressure of 20 μPa, the threshold of human hearing.
Transmission Loss	The loss in sound energy, expressed in decibels, as sound passes through a barrier or a wall. Measurements to determine a barrier's TL should be made in accordance with ASTM Recommended Practice E413-87. TL is determined as follows: $TL = 10\ Log_{10}\ [10^{(SPLs/10)} / 10^{(SPLr/10)}]$ (dB or dB(A)) where: SPLs is the sound pressure level on the source side of the barrier; and SPLr is the sound pressure level on the receiver side of the barrier.

Utilities — Transmission and distribution lines, pipes, cables and other associated equipment used for public services including, but not limited to, electric transmission and distribution, lighting, heating, gas, oil, water, sewage, cablevision, data communications and telephone.

Wavelength — The perpendicular distance between two wave fronts in which the displacements have a difference in phase of one complete period. (*Source: FHWA, 2017)*

2. REGULATION

Noise Barriers need to be installed on Roads/ Highways/Expressways to meet Ambient Air Quality Standards in respect of Noise as laid down by Central Pollution Control Board at recipient locations in the vicinity of the roads. The requirements as per the Noise Pollution (Regulation and Control) Rules, 2000 are given in **Box 2.1.** Any amendment to these Rules or issue of new legislation by the CPCB/ MoEFCC shall be updated from time to time.

Box 2.1 Ambient Air Quality Standards in Respect of Noise

Area Code	Category of Area/Zone	Limits in dB(A) L_{eq}*	
		Day Time	Night Time
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence Zone	50	40

Note:1. Day time shall mean from 6.00 a.m. to 10.00 p.m.

2. Night time shall mean from 10.00 p.m. to 6.00 a.m.
3. Silence zone is an area comprising not less than 100 metres around hospitals, educational institutions, courts, religious places or any other area which is declared as such by the competent authority
4. Mixed categories of area as may be declared as one of the four above mentioned categories by the competent authority.

* dB(A) L_{eq} denotes the time weighted average of the level of sound in decibels on scale A which is relatable to human hearing.

A "decibel" is a unit in which noise is measured.

"A", in dB (A) L_{eq}, denotes the frequency weighting in the measurement of noise and corresponds to frequency response characteristics of the human ear.

L_{eq}, It is an energy mean of the noise level over a specified period.

(Source: CPCB Website)

3. WARRANTS

Warrants for installation of noise barriers are as follows:

3.1. Monitoring of Baseline Noise

Baseline noise levels may be monitored for both existing and green field road projects near sensitive receptors like educational, health institutions, wildlife habitat, where first row (and storeys above ground floor) of buildings are residential for 24 hours during weekend and 24 hours during weekday (IFC,2007) considering atmospheric conditions. Where ever there are more than single storey receptors, adequate sampling shall be done on the top floor of such multi storey buildings[1].

3.2. Noise Level Prediction

Noise level prediction should be done using recognised mathematical models considering peak forecasted annual average daily traffic for the design period of road and atmospheric conditions.

3.3. Wildlife Study

Wildlife study, if required in accordance with latest MoEFCC/IRC/MORTH Guidelines/ Directions/Rules/ Norms, shall identify the type/ behaviour of animals, corridors being frequently used by the animals etc.

This will be helpful in identifying the appropriate noise barriers and the locations for their placement.

3.4. Minimum Selection Criteria

Minimum criteria for selection/ identification of noise sensitive receptors where installation of noise barrier would be required are given in **Table 3.1** along with indicative type of treatment.

Table 3.1

S. No.	Receptor	Minimum Selection Criteria			Indicative Type of Treatment
		Type	Intervening Land use between Road and Receptor	Sound Level	
1	Health Institution (HI)	HI with in-patient facilities & operation theatre	• Open land • Lower storey structure • Vegetation not high and opaque enough to obstruct sight line from the source	Forecasted sound level at receptor building is more than permissible limit during day (50 dB (A) or night (40 dB (A)	**Option 1**- On road treatment i.e., Installation of noise barrier along the road. Useful when receptor is continuous. **Option 2**- Off road treatment i.e., building or Boundary Wall treatments. Useful when receptors are discrete or in demarcated walled area like residential colony etc. This will also depend on the pattern and structure of the building/ boundary.

[1]During the monitoring, values should be recorded in both dB and dB(A) to better help choose the type of barrier to install.

2	Educational Institution (EI)	EI having primary section or above			Boundary wall treatment can include increasing the height of boundary walls / using metallic panels along or on top of boundary walls/ planting them with hedges/ doubling the wall thickness, carpeting with heavy or light porous concrete; use of hollow block concrete walls, unglazed brick walls. Building treatment can include thickening or carpeting of walls using dense or porous concrete,using noise isolating panels in windows/ doors, installing panels at a distance from the windows/ other openings considering them as receptors etc. (In case of off-road treatment responsibility of Maintenance (cleaning/ watering/ safety) shall lie with hospital / school/ administration/ resident welfare association. However, if there is requirement of re-installation/ replantation during the projected design period, that has to be done by the project proponent. This shall be mutually agreed upon while execution).
3	Residential	Continuous Residential structures in first row in urban areas		Forecasted sound level at receptor building is more than permissible limit during day (55 dB (A) or night (45 dB (A)	
4	Wildlife Sanctuaries/ National Park/ Eco sensitive zone or any other Notified Protected Areas (PA)/ recognised movement area/ corridors)	Elevated road section / overpasses traversing trough / along protected areas with mobile receptors	Not applicable	Forecasted sound level at nearest point is more than permissible limit during day (50 dB (A) or night (40 dB (A)	**If Elevated road section*** Absorbing noise barriers with a shade (of grey/off white/ light earthen colour or other soft tone colours) contrast to the surrounding shall be used. Barriers shall not act as mirrors and shall not be transparent. **If Overpasses*** If land and space is available, Earthen berms in combination with barrier wall that can

S. No.	Receptor	Minimum Selection Criteria			Indicative Type of treatment
		Type	Intervening land use between road and receptor	Sound level	
					can restrain the animals from toppling down the overpass as animals will have the tendency to climb on the earthen berm. (Earthen berm with vegetation will serve as a natural landscape) If land is not available then other feasible noise barriers should be used.
5	At grade existing roads traversing through PAs. Existing or new at- grade road outside the boundaries or PAs	• Open land • Vegetation and ground cover not high and opaque enough to obstruct sight line from of the highest animal that is found in greater frequency in the PA.		Forecasted sound level at nearest point is more than permissible limit during day (50 dB (A) or night (40 dB (A)	If land Space is available Earthen berm with vegetation cover may be a good solution. Overlaps shall be provided at identified corridor sections. Dimensions of opening between two parallel berms shall depend on the animal size frequently using the corridors. Slope of earthen berm shall be gentle enough at the road facing side to let animals climb easily in case they are stuck in the road side. Width of earthen shoulder/berm shall be enough to enable animals to wait in case of traffic.* If land is not available then other feasible noise barriers should be used.

*Shall be especially designed considering the type/biological behaviour of animals and surrounding terrain in consultation with the wildlife expert or any recognised guideline. In no case shall the barrier lead into fragmentation of wildlife habitat.

Note:

Static Receptors are those fixed at one place in terms of sensitive structures like health/ education institutes etc.

Mobile Receptors are those moving around over a large area like wildlife etc.

Discrete Receptors are individual receptors spread along the road at considerable intervals like school/ hospitals in rural areas etc.

Continuous Receptors are those present continuously along the road like residential areas in urban area/ protected areas

4. NOISE BARRIER DESIGN CONSIDERATIONS

This Section gives details of various design elements and aesthetics to be considered for a road noise barrier applicable for urban and rural settings.The technical and aesthetic considerations need to be taken hand-in-hand, as requirements of different sites may demand different solutions.

4.1 Length

Noise barriers should be long enough so that only a small portion of sound diffracts around the edges. If a barrier is not long enough, degradations in barrier performance of up to 5 dB(A) less than the barrier's design noise reduction may be observed for receivers near the barrier ends. As a rule-of-thumb,a noise barrier should be long enough such that the distance between a receiver and a barrier end is at least four times the perpendicular distance from the receiver to the barrier along a line drawn between the receiver and the road **(Fig.4.1).** In case of space constraints, the noise barrier ends can be curved inward towards the receptor (FHWA, 2017). However, in doing so, it shall be ensured that an angle of 80 degree subtended from the receptor edge falls on the curved arm of noise barrier **(Fig.4.2).** In case of flyovers/or elevated section, if the length of flyover is less than 4D, then length of the barrier should be at least equal to that of the flyover.

The length of 4D can be adjusted using formula (1) for spherical divergence and formula (2) for cylindrical divergence path of noise. Noise attenuation to be calculated for the distance from barrier side edge (noise level considered here is without barrier) to the edge of the receptor on both sides to attain the desired level of noise.

$L2 = L1 + 20*\log10(d1/d2)$ dB(A) ..... (1)

$L2 = L1 + 10*\log10(d1/d2)$ dB(A) ..... (2)

Where;

L1 is the sound level at distance d1; and

L2 is the sound level at distance d2

d1 is 1 meter from the source and

d2 is distance from source to the desired location.

As per FHWA 2017 Guidelines, Spherical divergence is that which would occur for sound emanating from a point source, e.g., a single vehicle pass-by. Cylindrical divergence is that which would occur for sound emanating from a line source, or many point sources sufficiently close to be effectively considered as a line source, e.g., a continuous stream of roadway traffic. (FHWA,2017)

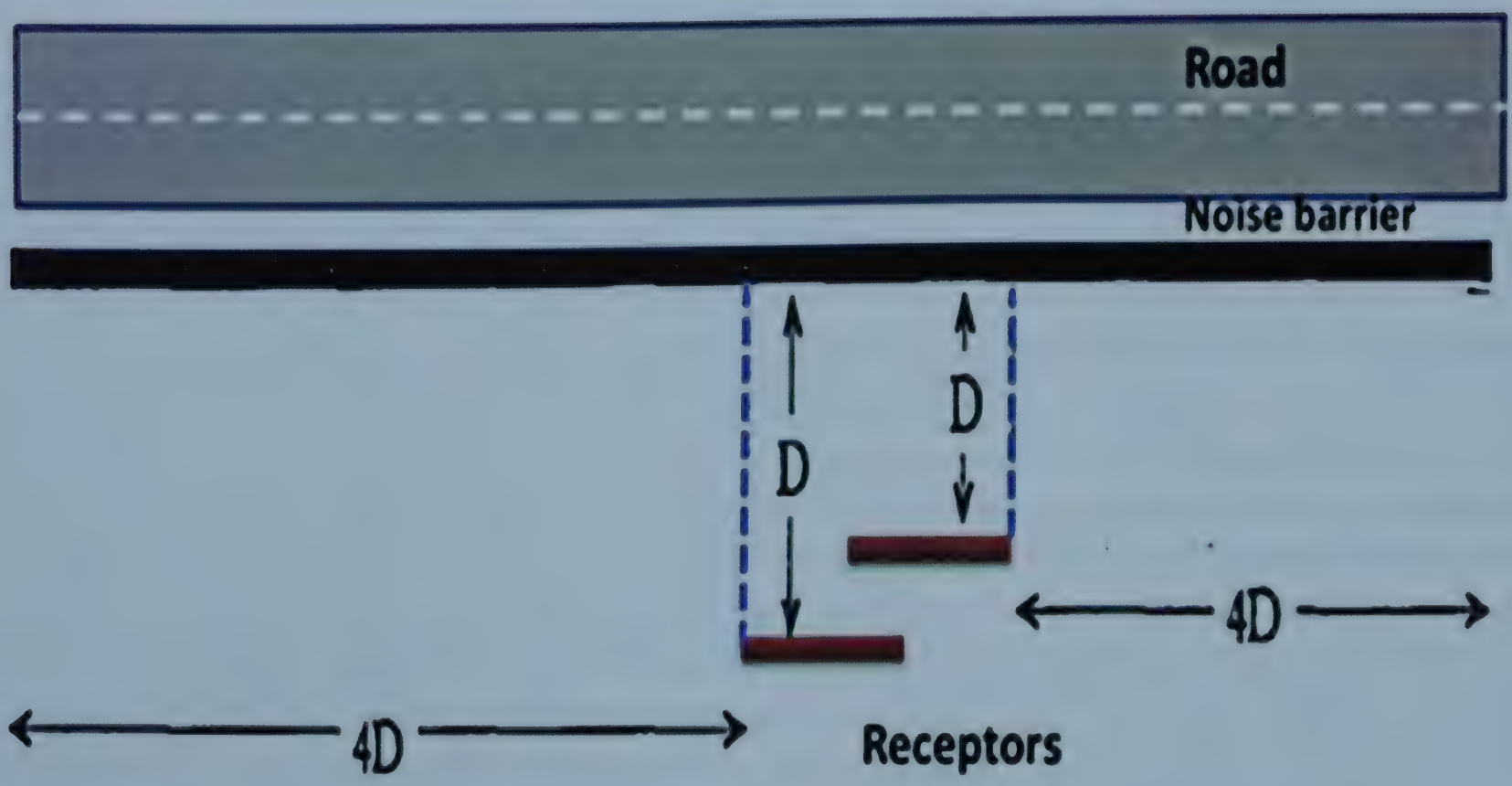


Fig. 4.1 Schematic Diagram for Fundamental Basis of Barrier Length

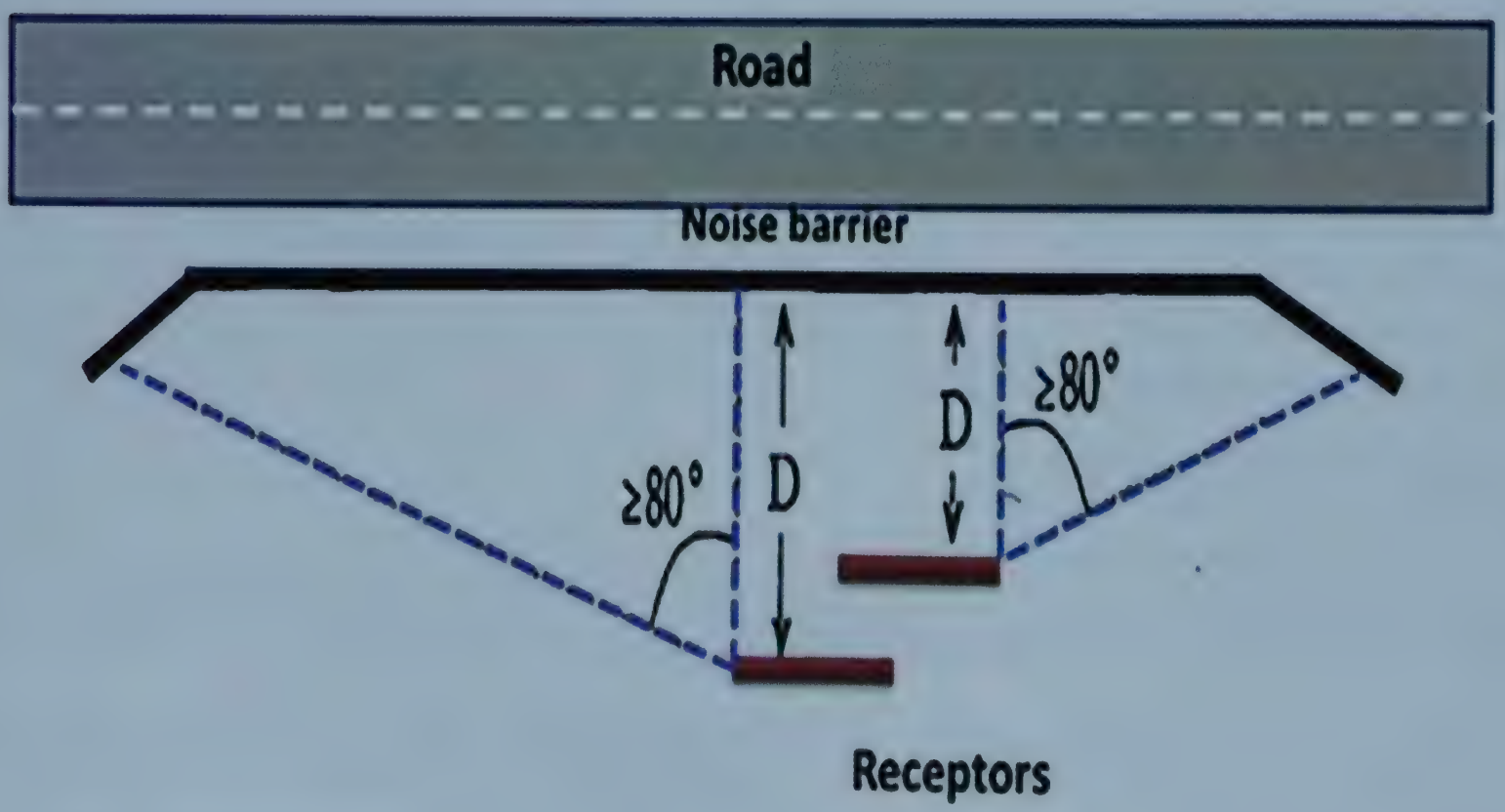


Fig. 4.2 Schematic Diagram for Fundamental Basis of Barrier Length with Curved End

(Source: Adopted from FHWA,2017)

4.2 Height

Height of a noise barrier would depend upon the height of receptor, width of road and height of source.

4.2.1 *Height of receptor*

Height of a noise barrier should be as much as to obstruct the line of sight from a receptor or obstruct the view of noise source. For instance, if the surrounding area is plain and first row of receptor buildings are single storey, then a noise barrier of at-least 1.8 m to 2 m height above ground shall be installed. Similarly, if it is an elevated road and the height of first row of receptors are more than or equal to the source, 1.8 to 2 m is the minimum height that shall be installed above the elevated road section. Basically, the psychological concept of out of mind, out of sight needs to be applied here. Obstructing the view is effective in reducing the noise level by around 5dB (A) and each additional 1m height would reduce the noise level by additional 1.5 dB (A) (FHWA, 2017). This will be due to diffraction loss or increased path length difference. Total noise attenuation would however depend on type and thickness of materials used for the barrier.

In case of existing boundary walls (off road attenuation measure), height can be raised by installing metallic panels/concrete barrier above the walls depending on their structural stability. Dense foliage of creepers supported on iron railing and barbed wire can also be used on top of walls to raise the height (needs to be site specific).

In case receptors are at multi-storey buildings along the road/ elevated section, different kinds of top treatment (T, Y, Cylindrical etc.) can be provided that have been explained later in these guidelines.

4.2.2 *Height width ratio*

Ratio of road width to barrier height should be more than 10:1. If the ratio of width to height is less than 10:1 then an insertion loss degradation of >3dB (A) is possible. It may be noted here that providing one side barrier would increase the noise level by 2 dB (A) than existing. Hence, it is preferable to provide parallel barriers on opposite side of the road/ elevated road section and for an effective noise attenuation the distance between the two should be 10 times the average height of the barriers. At a ratio greater than 10:1 and up to 20:1 the insertion loss degradation will be 0 to 3dB (A).

To reduce insertion loss degradation one or both side panels can be tilted outward **(Fig.4.3)** depending on site conditions. Even an angle of 7 degree can prove effective in reducing insertion loss degradation (Fleming, G. Get.al.,1994). Studies conducted in Europe, showed that for a 45 m separation, a tilt angle of only 3° was required to enable the full screening potential of the near-side barrier to be realised; however, for an 18 m separation, tilt angles of 10–15° were required. In case of 4 to 8-lane roads with median, to achieve the ratio, additional barriers can be installed in the median **(Fig.4.4).**

Fig. 4.3 Sound Barriers Tilted Outwards

Fig. 4.4 Barrier placed in the Median to Increase Path Length Difference
(Source: Benz & Colin, 2009)

4.2.3 *Height of source*

Noise emitted from road is due to friction of tyre with road surface, honking device and engine of vehicles. With the current fleet of vehicles, the engine and the horn are at an average height of 1.0-1.5 m. Hence, source height ranges from 0 to 1.5 m on an average. Barriers shall be higher than the maximum source height that can be determined based on mode wise traffic survey for the particular project.

4.2.4 *Top edge treatment*

Using different kind of top edge treatments in noise barrier depends on the basic concept of diffraction and shadow zone. A sound wave whose front has been changed in direction by an obstacle in the propagation medium (air) is a diffracted wave (FHWA, 2017). Diffraction can be caused by both the top and side edges. Due to the nature of sound waves, higher frequencies

(shorter wavelengths) are diffracted to a lesser degree, while lower frequencies are diffracted deeper into the shadow zone. The shadow zone represents a region behind the noise barrier where the barrier is effective at reducing noise levels (Wayne, 2016) **(Fig.4.5).**

At locations, where multi-storey receptors are present, it will be both technically and financially un-viable to keep increasing the barrier height beyond a certain extent. In such cases additional attenuation can be attained by increasing the number of diffractions at the top edge of barrier and that is possible by providing top edge treatment i.e., T –top, Y-top, Cylindrical, Mushroom, Pear-shape, Curved top etc. Top edges with absorptive/ soft materials are likely to be more effective.

One can choose the top edge shape by comparing the height of shadow zone extended by various types of top edge shapes. To do so one can draw a straight line from the maximum source[2] height or height of vehicle mode that has the highest frequency of movement, whichever is greater, as a tangent to the top – edge up to the receptor on both sides. The one that covers the maximum receptor height within the shadow zone can be chosen. A schematic diagram comparing the shadow zones for plain vertical and few other top edges is given as an example in **Fig.4.6.**

It is considered advisable to map some simple information during design study of roads so as to facilitate noise barrier designing easily viz.

a) Distance from source to proposed location of noise barrier

b) Maximum height of receptor

c) Distance of receptor from proposed location of noise barrier

d) Maximum feasible height of plain vertical barrier

e) Apparent Source Height-This should include both maximum and average source height of majority vehicle types. This has to be decided based on the types of vehicles captured in traffic study. Some sound waves incident on the noise barrier tends to reflect back towards the road and again gets reflected back by-passing vehicles increasing the apparent height **(Fig.4.7)** of the source.

For a large vehicle travelling at a high speed, where a reflective barrier is installed, there is a reduction in noise level on approach and departure of the vehicle. However, when the vehicle is close to the receiver, there is no significant reduction in noise. On approach and departure, the expected barrier attenuation is achieved as the sound travelling towards the receiver is reflected either ahead or behind the vehicle. When the vehicle is at its closest point to the receiver, the reflected sound falls onto the side of the vehicle and is, in turn, reflected onto the barrier. This process continues until the sound reaches the top of the barrier where it is diffracted towards receiver. These multiple reflections effectively raise the height of the noise source to near the top of the barrier and hence there is little or no path difference between the direct and the diffracted rays. For a steady stream of traffic, some of the sound reflected to the front or the rear of the vehicle would be reflected by other vehicles and thus the attenuation provided on approach and departure of a particular vehicle would be slightly reduced.

[2] Height of the source shall be measured vertically above centre line of each lane in a Carriageway as it is farthest lane of traffic which dominates the noise at the receiver.

An effective way to get rid of the apparent height consideration is to use absorptive noise barriers (explained later in these guidelines) or tilt barriers outwards so as to reflect the noise above the receiver rather than towards it.

There have been many research works related to top edge treatment and some of them are mentioned here for reference. Most of the top edge treatment with 500 mm width can reduce an additional 2 dB(A) of noise (Kohei, 2015).

T-shaped Top: In full scale model tests, the Transport Research Laboratory (TRL) of the United Kingdom reported benefits of 2–3 dB(A) when using 1 m and 2 m wide tops which were faced with sound absorption, and a 1.4 dB(A) benefit for a 1 m wide reflective top **(Fig.4.8)**, These results are broadly consistent with other researchers and represent more benefits than can be explained by the cantilever effect.

Y-shaped Top: A novel Y-shaped barrier has been developed in Japan which has two small Y-shapes at the ends of a larger Y-shaped barrier, thus creating four diffracting edges **(Fig.4.9).** The traffic side of the barrier and the insides of the small Y-shapes are lined with sound absorption.

Tubular Capping: Tubular elements installed as a capping on top of vertical barriers may also be used. The most popular forms are either cylindrical or mushroom-shaped and are fabricated with reflective or sound absorptive materials **(Figs.4.10 and 4.11).**

Tubular capping with Planting Box: Using the hollow space between tubular capping for plantation of small shrubs **(Fig.4.12)** will serve dual purpose of increased height for noise attenuation and increasing green cover. This option is maintenance intensive. This concept however can be used effectively while providing off-road treatments on boundary walls of receptors.

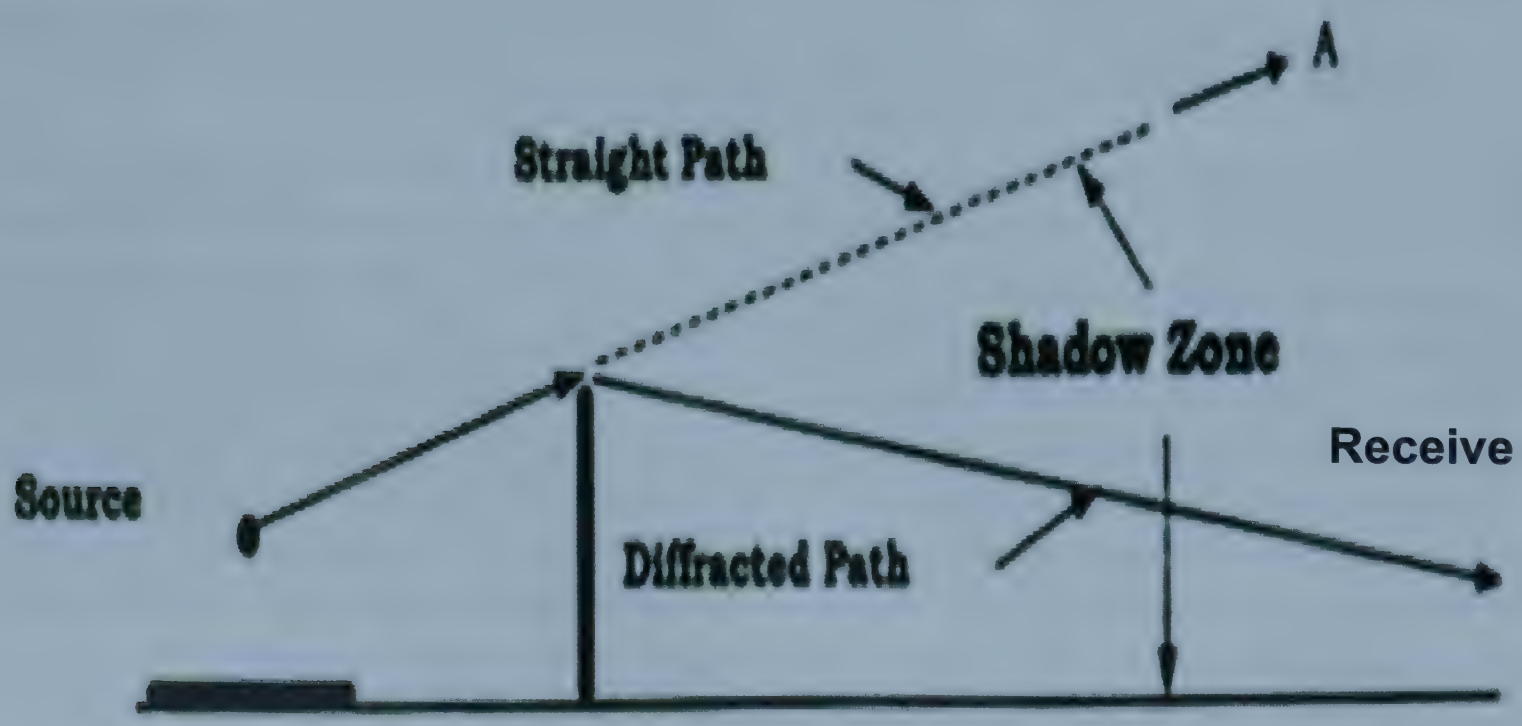


Fig. 4.5 Barrier Diffraction and Shadow Zone (EPD,2006)

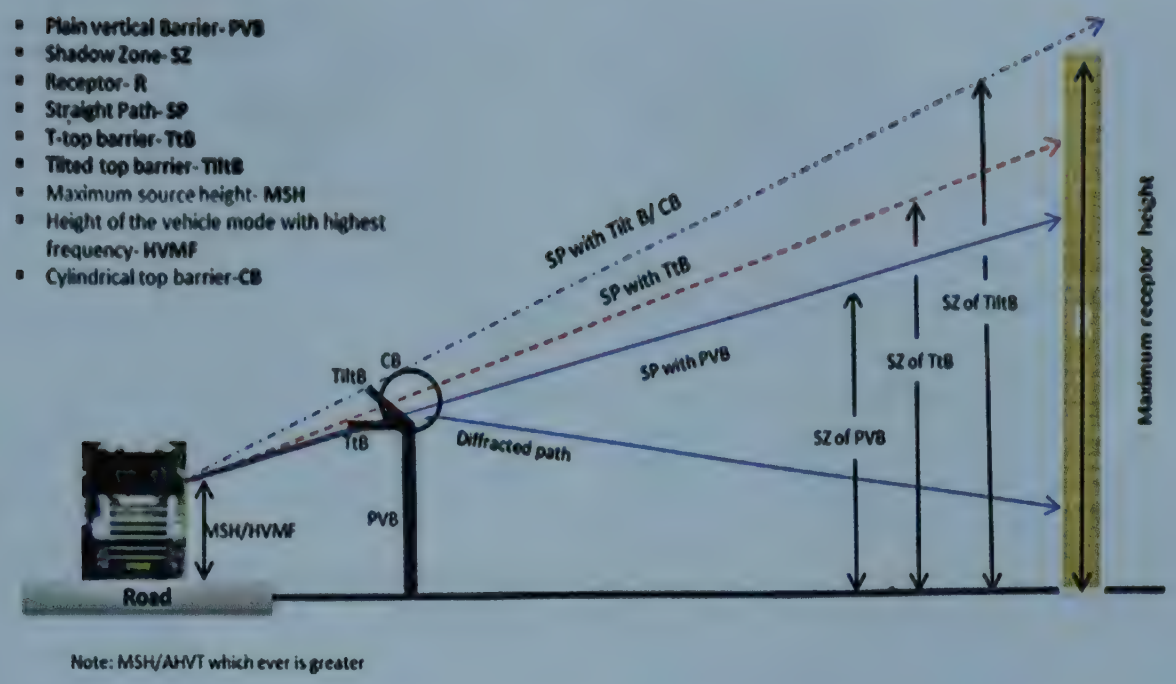


Fig. 4.6 Relationship of Shadow Zone and Various Barrier Top Treatment-A Schematic Diagram

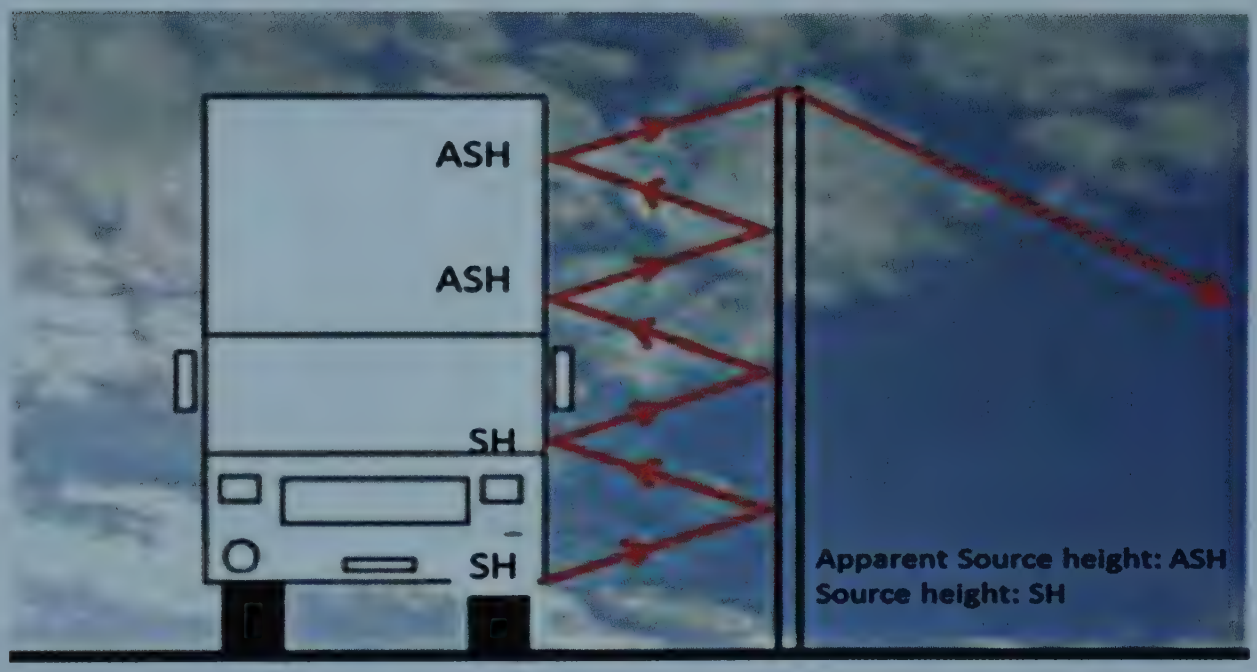


Fig. 4.7 Apparent Source Height and Actual Source Height

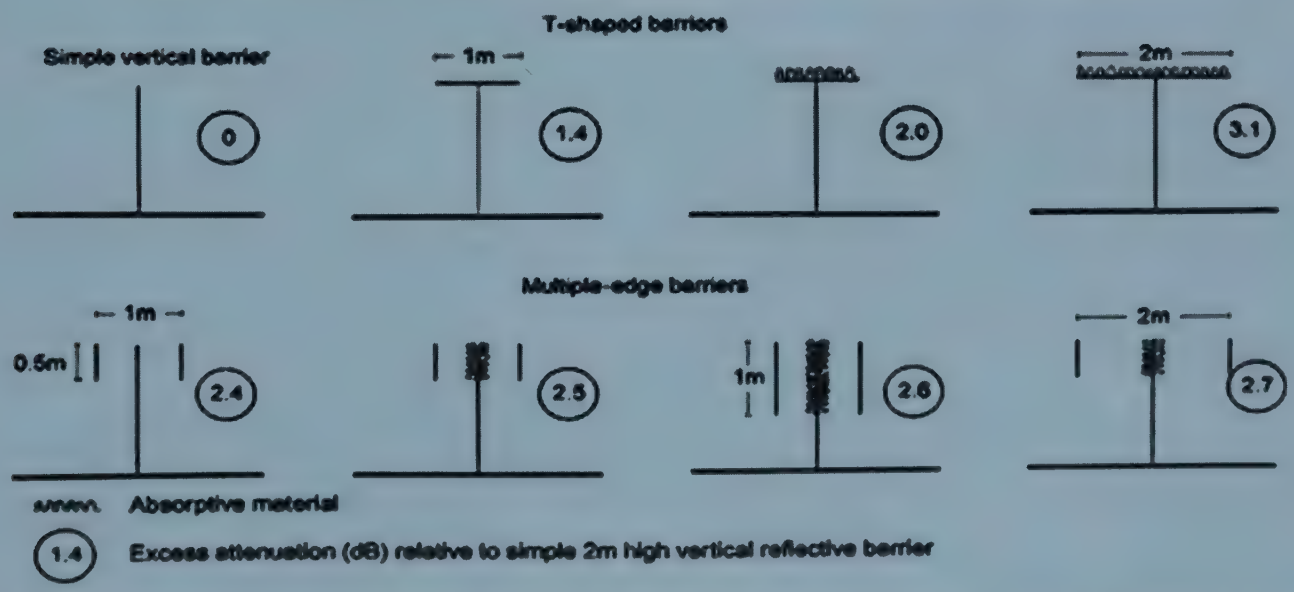


Fig. 4.8 Relative Insertion Losses of T-Shaped and Multiple Edge Barriers compared to Vertical Barrier

(Source: Benz & Colin, 2009)

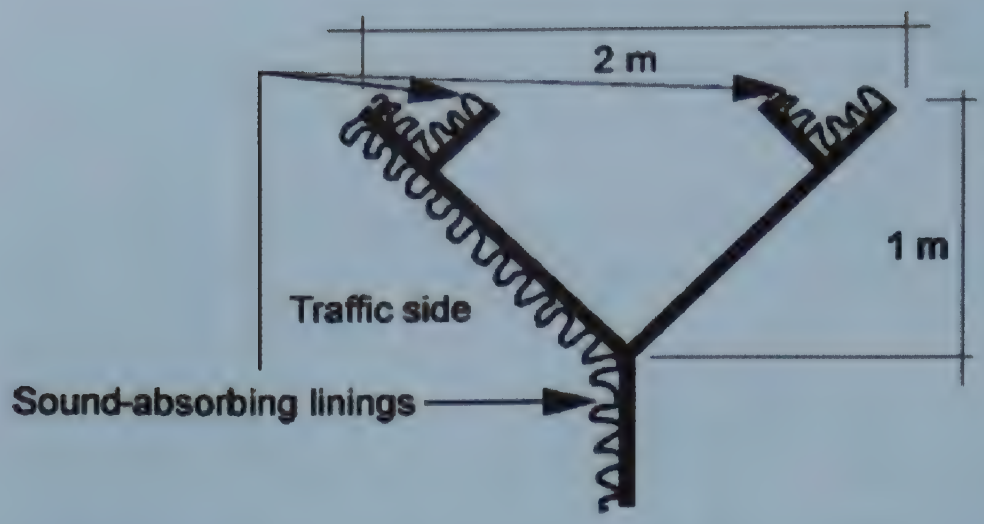


Fig. 4.9 A Multiple Y-shaped Barrier (adapted from H. Shima et al.)
(Source: Benz & Colin, 2009)

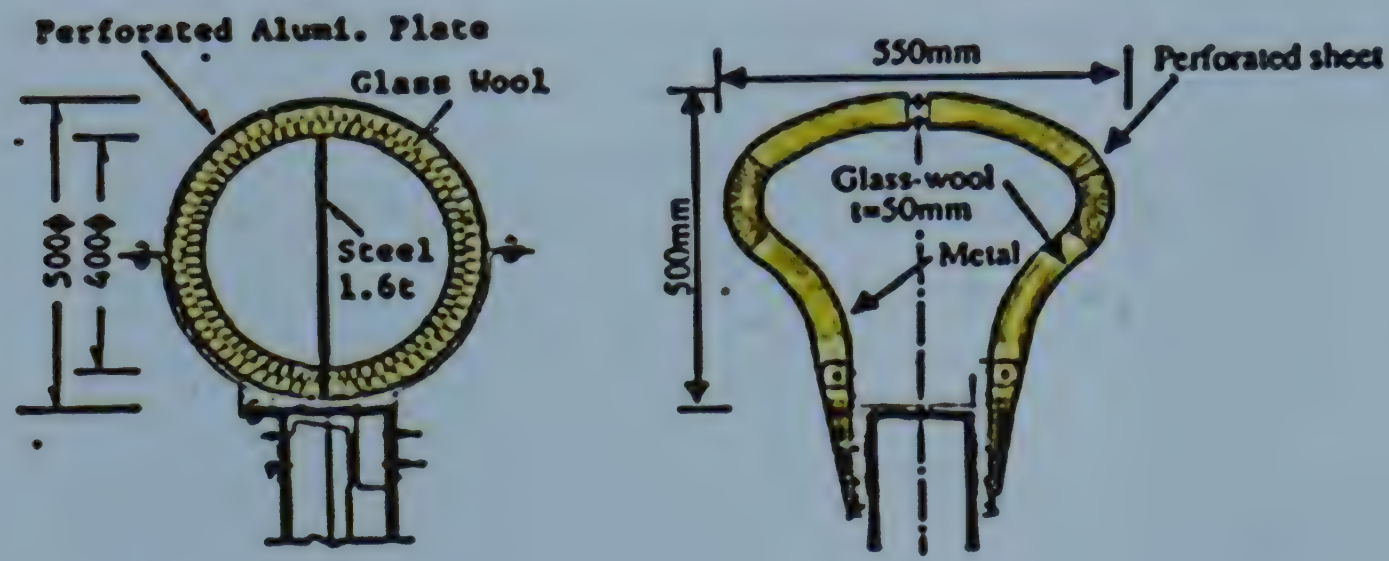


Fig. 4.10 Cross-section of Cylindrical and Mushroom Shaped Barrier
(Kohei, 2015)

Fig. 4.11 Tubular Shaped Barrier Constructed along Road
(Source: B enz & Colin, 2019)

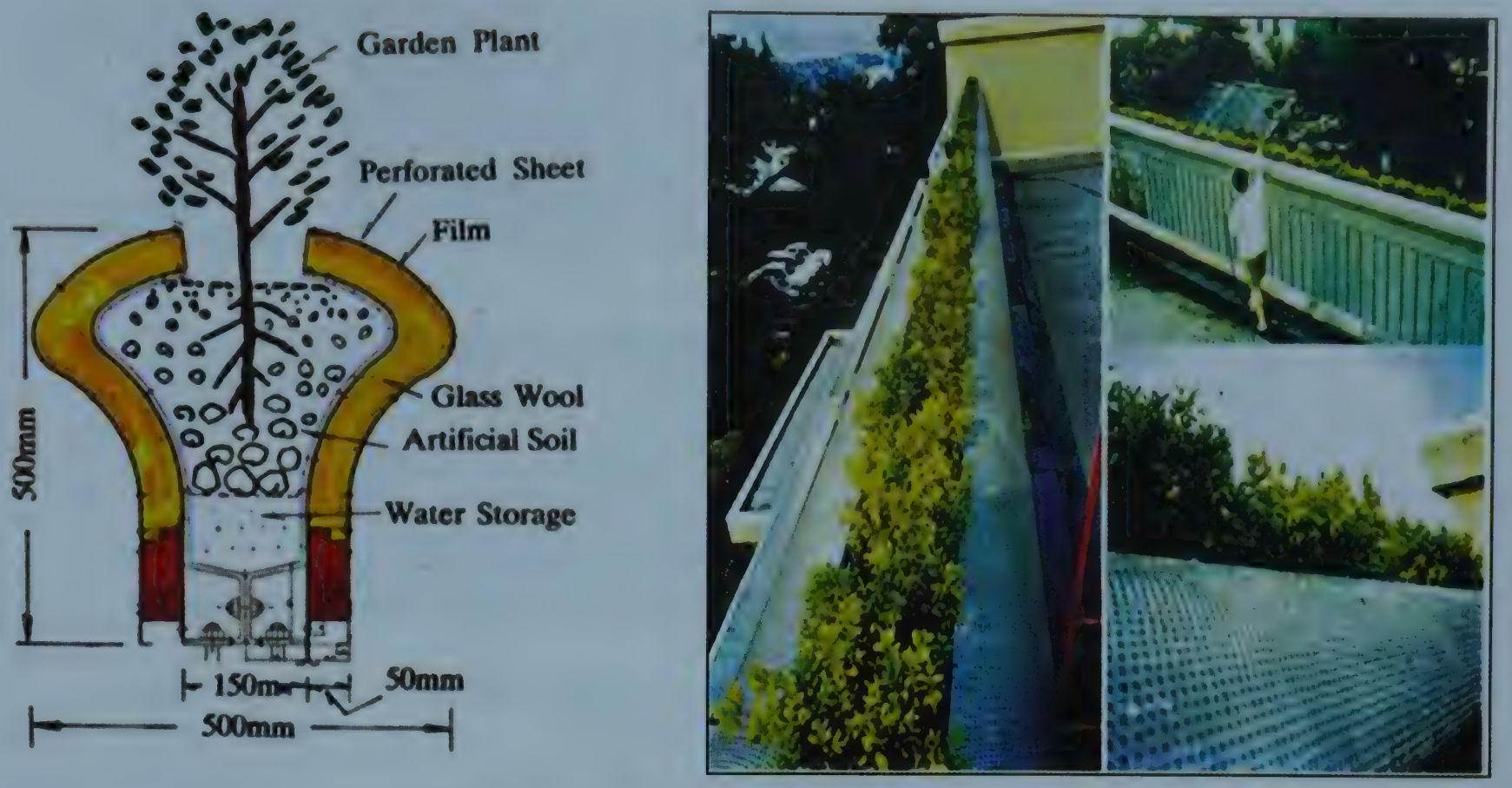


Fig. 4.12 Mushroom Capping with Planting Box

(Source: Benz & Colin, 2009)

4.3 Barrier Placement

To obtain the optimum performance from a barrier, it is desirable to place it as close to the road as possible. This applies where the road and the receiver are at-grade, or where the road is elevated on an embankment or viaduct **(Fig. 4.13**). The same performance can be obtained by placing the barrier close to the receiver in case of providing off-road/ building treatment for discrete receptors some distance from the road. Regarding the placement of barriers, the following points need to be considered:

- In case a crash barrier is present, noise barrier (or the protruding top edge as the case may be shall be placed at a safe distance behind the crash barrier. In the case of rigid (concrete) barriers, it can be placed on top of the barriers considering the criteria of safety.

- In case of providing on-road treatment where a crash barrier is not installed, it shall be noted that the noise barrier should be placed at a distance not less than that recommended for, from black top edge to crash barrier for ensuring safety.

- It is to be noted that a noise barrier cannot act as a crash barrier under normal circumstances, unless the system has been specifically tested for the combined use - i.e., as a Crash Barrier (as per guidelines in IRC:119) and a Noise Barrier (as per these guidelines).

At locations, where the road is in a cut section, or receptor is in a raised platform, the barrier should be placed at the top of the cut slope **(Fig.4.14).**

Fig. 4.13 Barrier should be placed as close to the road as possible on Flat or Elevated Ground

(Source: Benz & Colin, 2009)

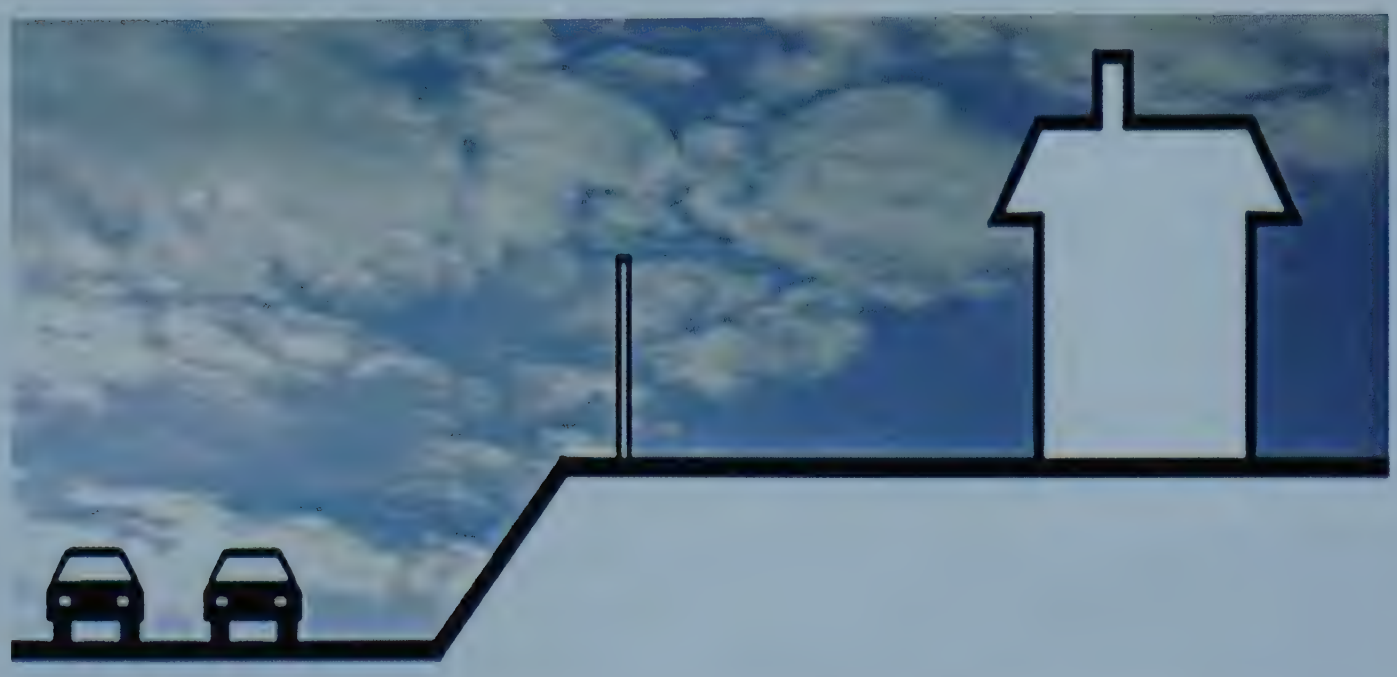


Fig. 4.14 Barrier should be placed at the Top of the Cutting Slope

(Source: Benz & Colin, 2009)

Placement of barriers and use of different types of barrier (details given later in these guidelines would depend on the landscape,occurrence and type of the sensitive receptors **(Table 4.1)**. Though absorptive barriers perform better in terms of apparent source height, reflective barriers can be used in case of open landscape where apart from the identified discrete receptors, no other receiver is present in the surroundings. In case of open areas that form part of wildlife movement areas but does not fall within the notified wildlife sanctuary or eco-sensitive zones/ areas, reflective parallel barriers can be used. However, it must be noted that reflective barrier shall not be used in case of areas near bird sanctuaries as it will create a linear invisible wall of sound for avifaunal species at the airspace above a road corridor.

Table 4.1 Suggested use of Different Types of Barriers and their Placement depending on Landscape

Landscape	Static & Discrete	Static & Continuous	Mobile
Rural habitation	Off road/building treatment- absorptive	On road- absorptive barrier or barrier with high TL value	
Open area	Off road/ building treatment- reflective	-	On road- reflective
Urban dense settlement	-	On road- absorptive barrier	
Natural Habitat (Wildlife /Bird Sanctuary etc)	-	-	On road- absorptive barrier
Note: On road barriers or barriers within road ROW in case receptors are continuous and static/ continuous and mobile/ discrete and mobile; Off road or building/ boundary wall treatment in case receptors are discrete and static.			

4.4 Noise Leakage through Gaps

Sound "leaks", due to holes, slits cracks or gaps through or beneath a noise barrier, can seriously reduce the barrier performance, and should be avoided. Any gaps represent segments of the barrier with zero Transmission Loss; that is, the gap can be considered to transmit 100% of the energy incident on it. Therefore, extra efforts should be made during design and construction stages to avoid holes, slits or gaps, either with the adjoining panels, along the bottom edge or gaps, construction joint or expansion joints.

In case gaps have to be left in barriers for emergency access and maintenance, the acoustic performance of the barrier should be preserved by erecting a parallel, additional overlapping barrier behind the gap. One face of the overlap must be lined with sound-absorbing material to prevent reverberation within the gap. The length of the overlapping section should be at least thrice the gap length (d) or d+2(a) whichever is more **(Fig.4.15)**.

In case of single side overlapping the length of overlapped section should be 4 times the distance between the two panels (FHWA, 2017) **(Fig.4.16)**. This shall be applicable in case of earthen berms in wildlife sanctuaries or protected areas as well.

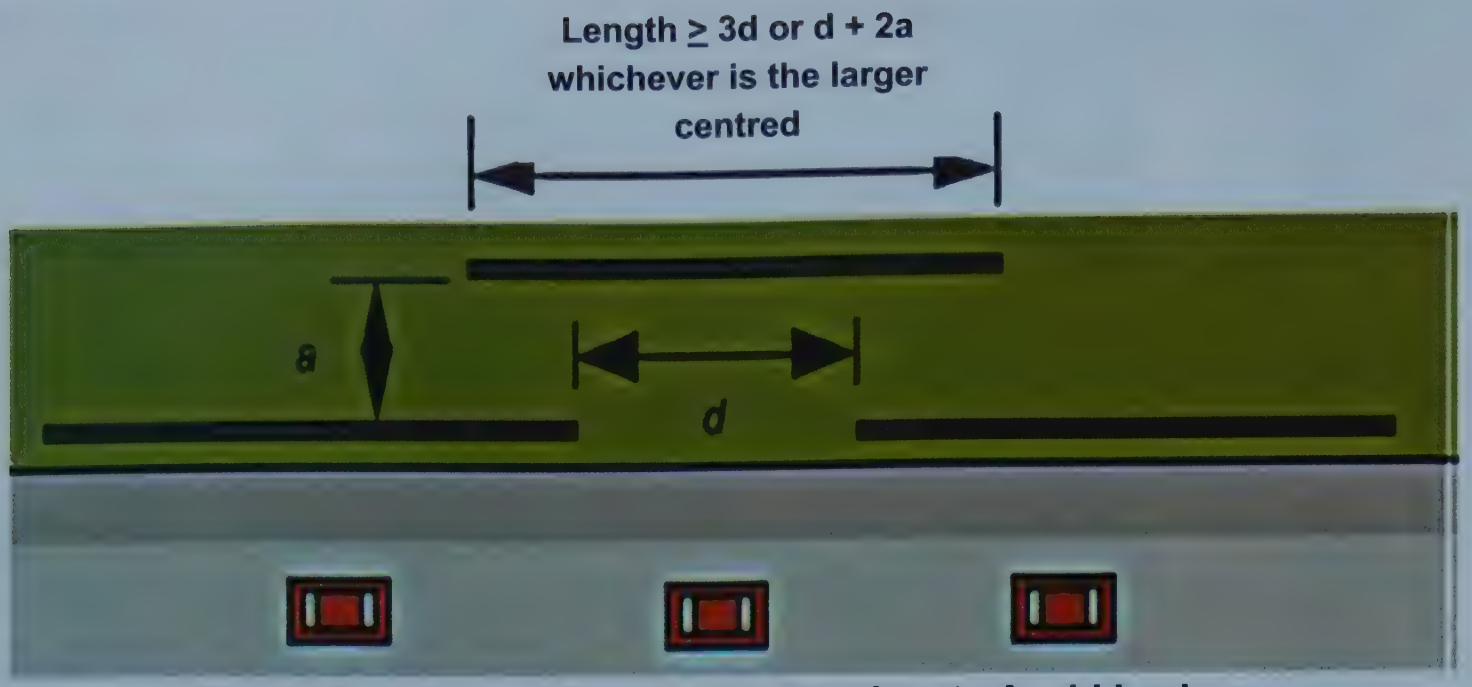


Fig. 4.15 Additional Overlapping Barriers to Avoid Leakage

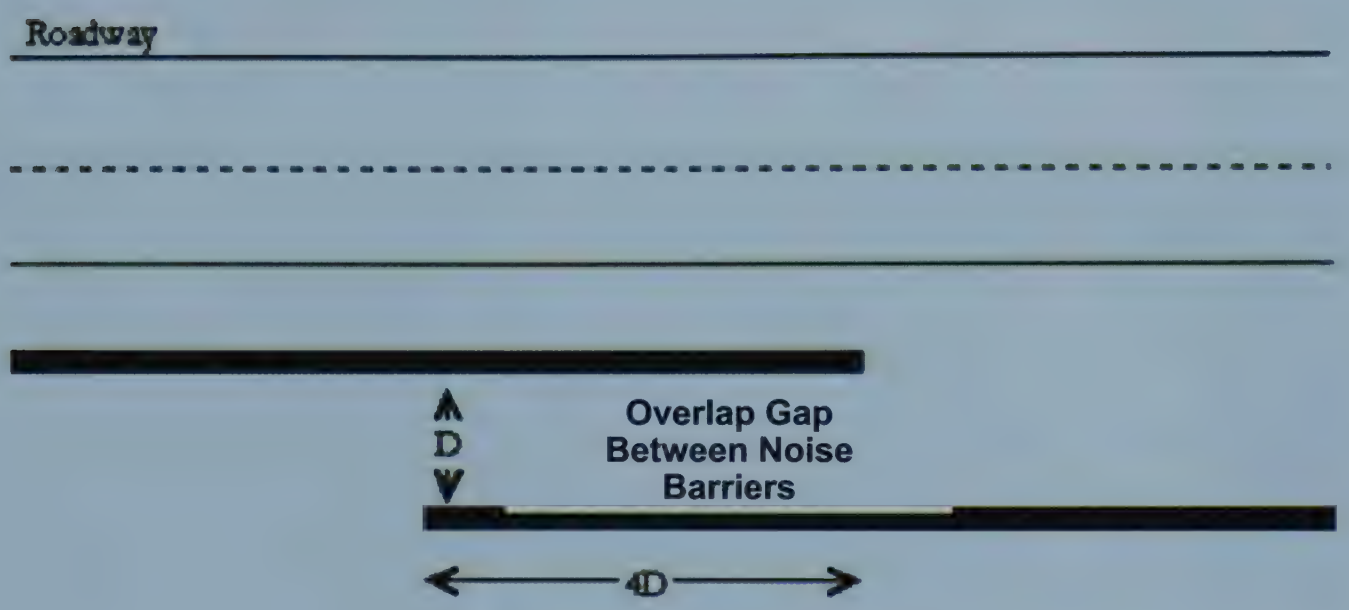


Fig. 4.16 Overlapping Barrier

(Source:FHWA, 2017)

4.5 Aesthetics

Aesthetics is an integral part of both design and safety of road users as well as mobile receptors.

4.5.1 *Colours*

Colours of noise barriers are an important aspect in terms of safety. Following points shall be considered while choosing an aesthetically pleasing colour in different landscape.

a) **Human Settlement (Rural/Urban)**

- **Anti-Glare Properties:** Muted tones of colour shall be chosen to avoid anti-glare effect that can compromise the safety of road users.
- **Surrounding Architecture:** Muted/softertones of blue, green, grey brown or earthen tones should be selected to blend with the surrounding architecture.Alternatively, the help of an architectural expert can be sought to design a Barrier as a stand out installation to enhance the visual appeal of the surroundings.

b) Protected Areas or Wildlife areas

A muted/ softer tone of colour shall be chosen that can be easily distinguished by the mammals and avifauna from the surroundings. This will prevent birds and arboreal species from striking the panels and hurting themselves. The anti-glare property of panels is equally important here as well.

4.5.2 *Transparent vs opaque and mirror effect*

a) Human Settlement (Rural/Urban)

- **Tunnel Effect:** Narrow (2-lane or less) and long (1 km or more) roads/bridges/ flyovers having only opaque barriers can cause tunnelling effect for the road users thus it shall be preferred to use a mixed barrier comprising of Transparent and Opaque Barriers. It is advisable to keep the transparent panels either in the line of sight of the vehicle drivers or on top most allowing maximum light to penetrate through. In an Indian environmental condition, putting the transparent panel on the bottom most part is not advisable as there are higher chances of it accumulating dirt and thus defeating the purpose of the transparent panel or avoiding tunnel effect.

- **View of Landscape:** It may be appropriate to allow the view of landscape by using transparent barriers but it may be disturbing the view from opposite side (i.e. resident / receptor side). Hence, with transparent barriers, the very concept of out of sight, out of mind gets defeated. Therefore, it is advisable to use opaque/ translucent barriers in settlement areas or mixed use of transparent and opaque panels.

- **Mirror Effect:** The barriers shall not have mirror effect or image reflecting properties on the road side. The protected side can have mirror effects, if the surrounding architecture allows it to be so.

b) Protected Areas or Wildlife Areas

- **Glare Disturbance:** Opaque barriers are advised to be used in a protected and/or wildlife areas so that the glare of vehicle light does not disturb the animals on the other side.

- **Illusion of free passage:** Opaque Barriers should be preferred for such installations over transparent ones as transparent barriers can create illusion of obstruction less passage for birds and animals. Transparent barriers can be hazardous for mammals and birds.

- **Mirror effect:** Neither road nor protected side of the barrier shall have mirror effect /property of reflecting image, otherwise it will have hazardous impact on birds and animals trying to fly or pass through.

- **Tunnel effect:** Narrow and long parallel barriers may cause tunnel effect for road users, but in protected / wildlife areas, wildlife shall be given preference above road users. Use of transparent or translucent barriers will cause disturbance to the wildlife and also can be hazardous.

4.5.3 *Pattern*

The relationship of different barrier elements (posts, panels, adjacent panels, caps etc.) is referred to as the barrier's pattern. Some examples of the wide variety of techniques that can be used to create patterns are by using different colour or colour shades or texture in posts and panels; creating bold and large self-colour designs **(Figs.4.17 to 4.21)**. The following points shall be considered with respect to pattern.

- **Breaking the Monotony:** On a long stretch of noise barriers, the pattern will help break the monotony for the driver. Pattern on the road side shall be bold and large compared to the community side. Patterns being large and bold gets easily visible to drivers without attracting too much of attention.
- **Viewing at Speed:** The design should be simple with clean lines and edges so as not to cause blurring when viewed from vehicles travelling at fast speed. Detailed patterns may divert driver's attention and compromise with safety.
- **Repetitive and Replicable:** The barrier components should be repetitive and readily replicable for ease of maintenance, continuity and avoid attracting too much of attention from drivers.

Fig. 4.17 Self Colour Bold and Large Patterns

Fig. 4.18 Different Texture Pattern

Fig. 4.19 Absorbing Panel with Different Colour Patterns

Fig. 4.20 Transparent and Absorbing Panels used together to Form a Pattern

Fig. 4.21 Noise Barrier with Striking Colour Patterns used as an Architerual Installation.

5. NOISE BARRIER TYPES, MATERIAL PROPERTIES AND SPECIFICATIONS

5.1. Type of Noise Barriers

Since sound energy falling on the barrier will either be reflected, absorbed or transmitted by the barrier depending on the type of barrier and material, it is important to choose the correct type of barrier depending on site and project conditions. Noise Abatement Barriers can be broadly classified into three types:

- Absorbing Noise Barriers (Mono and Bi-Absorbent)
- Reflective Noise Barriers
- Natural Barriers

5.1.1 *Absorbing noise barriers*

Absorbing barriers can be both Mono Absorbent and Bi-Absorbent depending on design and site requirements.These barrier systems not only isolate but absorb majority of the incident sound and reflect a relatively small portion. These are useful in both urban and rural environments. Absorbing barriers can be classified into:

- **Metallic Sandwich Absorbing Barrier-** Based on type of metal this can be further classified into Steel and Aluminium Sandwich Absorbing Barrier.
- **Wood Sandwich Absorbing Barrier**
- **Concrete Wall Absorbing Barrier**

5.1.1.1 Metallic sandwich absorbing barrier

The Barrier usually consists of an absorbing face with porous metallic sheet towards the source of the noise and a solid reflective side facing the receptor being protected for mono-absorbent barriers, In case of bi-absorbent barriers, the porous metallic sheet is present on both faces of

the panel. These are usually opaque sandwich panels of steel/aluminium with an absorbing material panel sandwiched between them. A layer of glass veil is provided after the porous metallic layer followed by mineral/rock wool or a water -repellent mineral/rock wool slab shall be provided and then the solid metallic panel is placed.

The sound waves from the source pass through the perforated panel and fibre glass veil and then go through the absorbing material panel. The Absorbing Panel is highly porous in nature and thus the high intensity sound waves entering it go through multiple reflections and are broken down into low frequency waves due to the loss in energy, thus resulting in absorption of the sound waves. The sound waves which are not absorbed, pass through the absorbing material and hit the impervious plain sheet at the back of the panel. These waves then get reflected back into the absorbing material. This further results in some more absorption of the sound and the unabsorbed sound is reflected back into the atmosphere towards the source. There are different types of noise absorbing materials available, which can be used inside the barrier. The absorbing capacity of the barrier depends upon the acoustic property of the infill material. The different types of infill materials used are Recycled Rubber, Rock Wool/Mineral Wool, Polyester Wool, Aluminium Foam, Acoustic Cotton, Plastic Foam and High-Density Polyurethane Foam.

The absorbing material can be susceptible to damage due to rainfall and thus the water repelling protective thin layer of fibre glass cloth (glass veil) should be pasted on the absorbing side of the panel to prevent damage from the water. Alternatively, the absorbing material slab can be a water-repellent mineral/rock wool slab to prevent the damage from the water. The treatment of the absorbing panel should ensure that the lifespan of the absorbing panel is in accordance with the design life of the Noise Barrier. A small hole should also be provided in the bottom of each sandwich panel to ensure the drainage of any water that seeps through.Typical Diagram of a Metallic Absorbing Noise Barrier Panel is given in **Fig.5.1**.

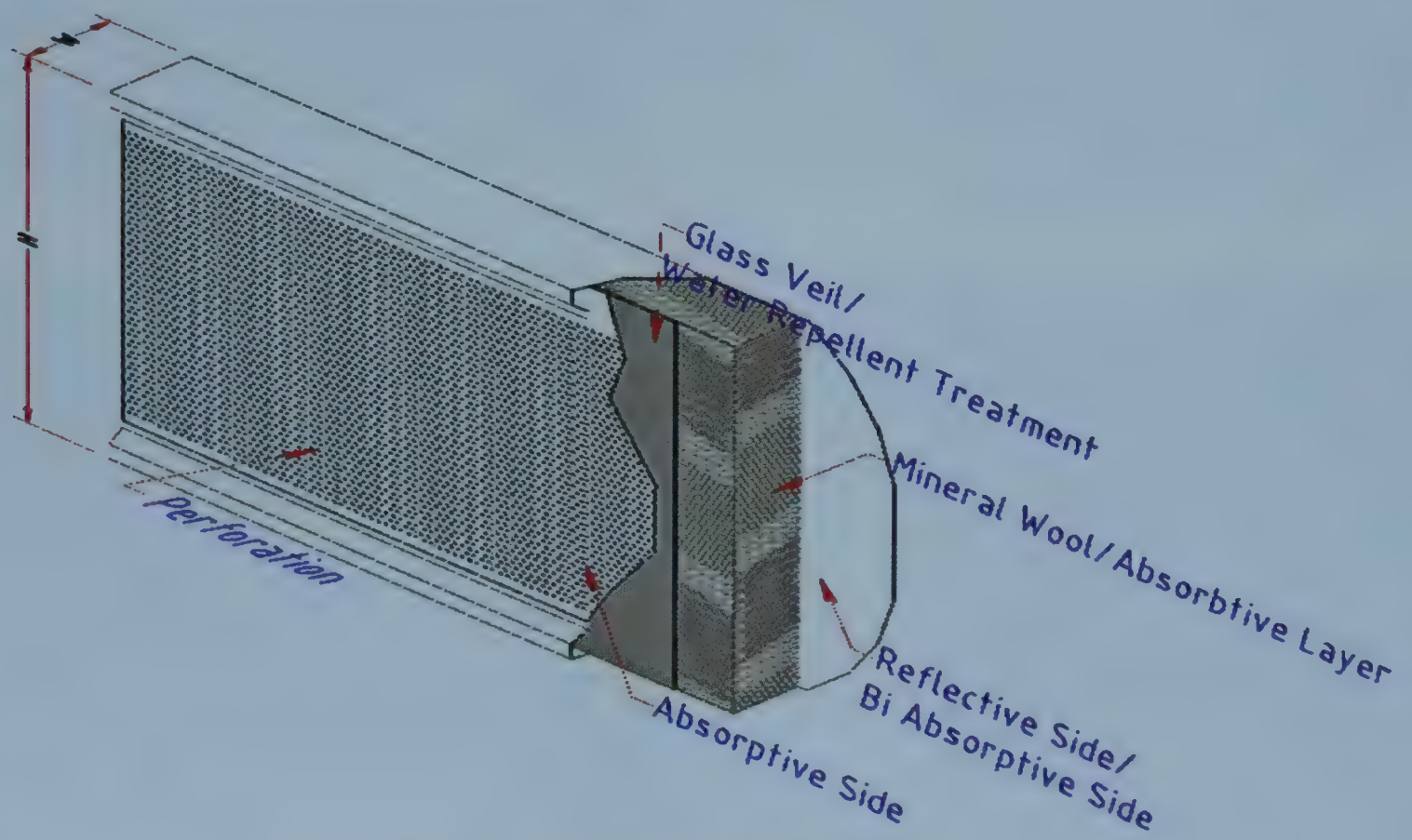


Fig. 5.1 Typical Details of a Metallic Noise Barrier

NOTE: Dimension/Parameters will vary as per manufacture design

The Metallic Panels length may vary between one to six meters depending on the structural requirements of the site. The panels are installed on foundation supported steel columns of HEA/HEB/HEM or UC[3] type and can be installed both on the ground as well as on reinforced concrete parapets. A General Layout of a Metallic Panel is given in **Figs.5.2** and **5.3**

These Panels can typically isolate around 28-30 dB of sound and absorb around 20 dB.

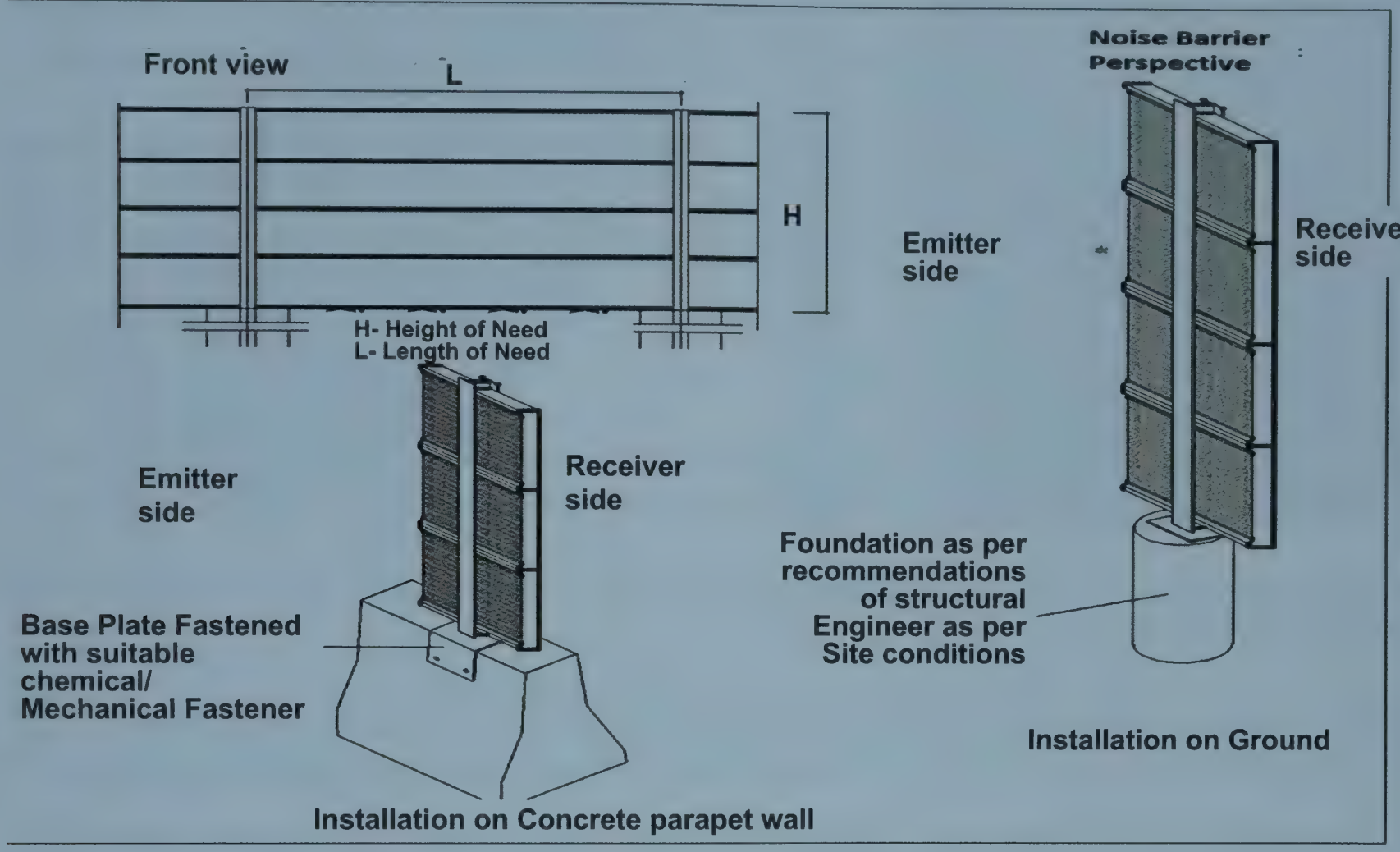


Fig. 5.2 General Layout of Metallic Noise Barrier

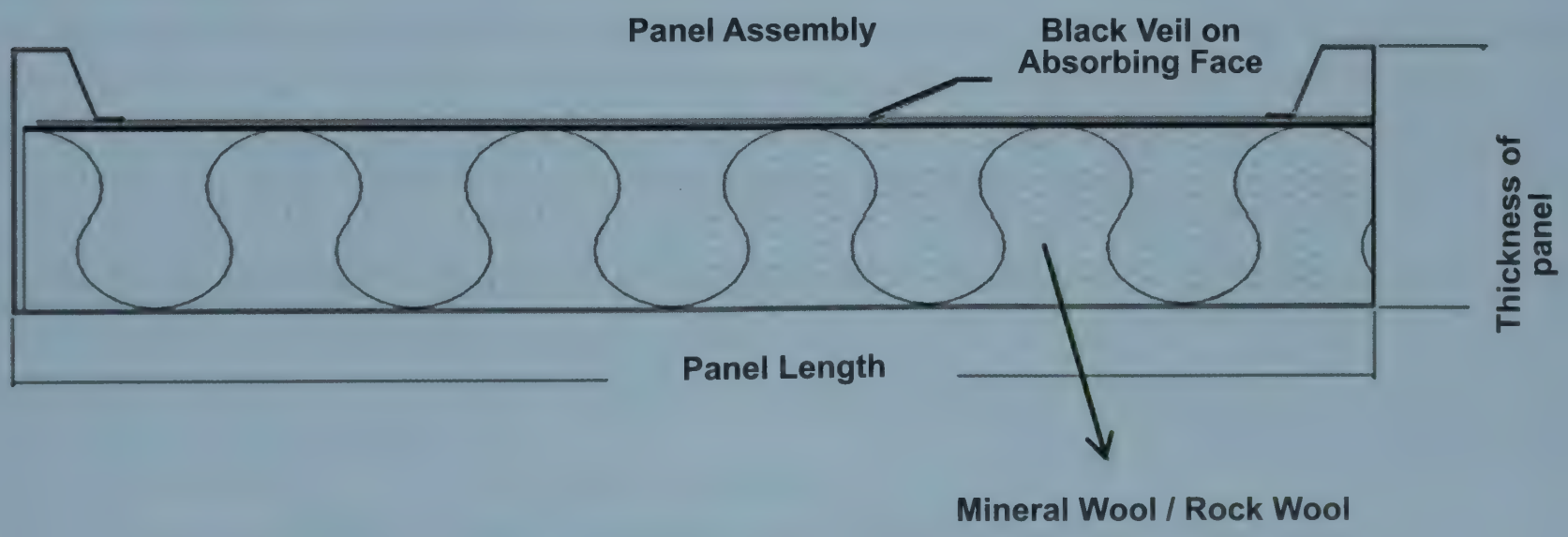


Fig. 5.3 General Cross-Section of Metallic Noise Barrier Panel

[3]Both HEA/HEB Columns denote Parallel Flange Beams with H indicating H-Section Beam, E indicating European Type and the letters A, B, M distinguish the various series of the same nominal size, with A indicating the light series, B the normal series and M the reinforced (UNI 5397), whereas UC denotes Universal Column Beam of I or H cross sections.

5.1.1.1.1 Steel noise barrier panels

Steel Noise Barrier is an opaque panel made of either Galvanized Steel with Powder Coating or Specialized Steel such as Magnelis steel, Corten steel or hot dip aluminium zinc -alloy metallic coated steel having a corrosion resistance of minimum 15-20 years.

The panel shall be as per the manufacturer's design as long as there is a certified report provided to establish the structural stability of the panel as per site conditions by a certified Structural Engineer.

Steel used shall be structural steel of IS:2062, IS:15961 hot dip aluminium zinc -alloy grade structural steel hot dip galvanized or IS:277 Galvanized Sheets which are then powder coated of colour and of thickness as per manufacturer's design pertaining to structural stability and acoustic properties as per site requirement.

5.1.1.1.2 Aluminium noise barrier panels

Aluminium Noise panels although more expensive than steel, are useful when a light weight panel is required especially when installing on top of structures or in areas prone to rapid corrosion.

The design of the panel would be as per manufacturer's specifications, and design shall be tested for both acoustic and physical properties.

Aluminium shall be of grade ALU 1050A/ALU 3004/ALU 3105 or equivalent depending on the design. Manufacturer must establish structural stability of panel to show feasibility of design.

5.1.1.2 Wood sandwich absorbing barriers

Wood Noise Barrier Panels consist of a back panel made out of Dove Tailed Slats and inner frame of wooden battens and front panel of Wooden Slats with appropriate gaps to allow sound waves to pass through. The shell of the panel is filled with rock/mineral wool covered with polypropylene. The design and dimensions of the material used would be as per the manufacturer's design tested for both acoustic and physical properties.

The wood used should be vacuum and injection treated to withstand prolonged exposure to the open environment and the manufacturer should produce requisite documentation in this regard along with acoustic and physical certification as in some areas they can be very much prone to termite or similar worms.

The panels are installed on foundation supported steel columns of HEA/HEB/HEM or UC Type and can be installed both on the ground as well as on reinforced concrete parapets.

A 100 mm thick wooden noise barrier can isolate up to 29 dB of sound and absorb around 8 dB. Typical Diagram of Wooden Panels is given in **Fig.5.4.**

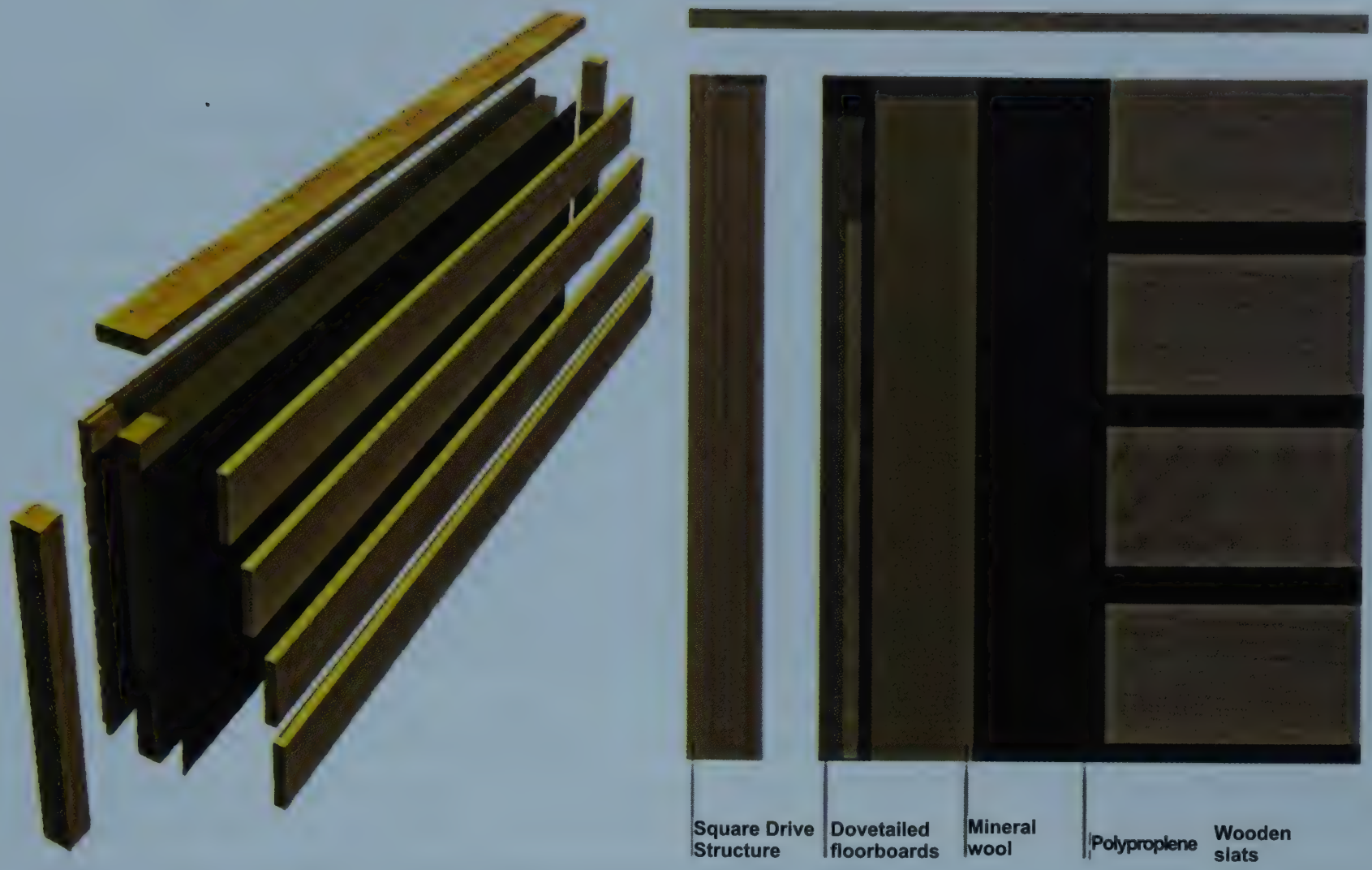


Fig. 5.4 Typical Diagram of an Absorbing Wooden Barrier

5.1.1.3 Dense and porous concrete wall absorbing barriers

Concrete Barriers may comprise of Pre-fabricated Panels interlinked to each other or Cast-In Situ Panels cast at site. They are primarily used as boundary walls or counterweights in tall noise barrier installations. The Barriers usually have a lifecycle of around 40 years and can be painted or treated with various treatments to increase their lifespan.

Dense and Porous Concrete Barriers are precast panels of concrete of both High Density (approximately 2400 kg/m^3) and Low-Density Concrete (approximately 1682 kg/m^3). The Dense Concrete forms the base of the panel with a profiled section of Low-Density Concrete on Top. Such a panel is usually preferred to reduce the weight of the concrete panel to be used as an Acoustic Barrier. The lightweight aggregates normally used are expanded shale, clay, or slate materials that have been fired in a rotary kiln to give them a porous structure. These barriers are more absorbing compared to dense concrete barriers due to the porosity. The Panels can isolate around 47dB of Sound and Absorb around 4 dB due to the porous nature of the low-density concrete. A typical representation of such a panel is given in **Fig.5.5.**

Each panel shall be constructed as one piece and be devoid of any joints, so that it allows easy mounting and dismounting on the support profiles and may consist of the following elements and materials:

a) **Insulation and structural concrete plate:** It should be made, with concrete at least type M-30 for structural stability. In the event that the height of the acoustic screen requires

the placement of several concrete panels, Ethylene Propylene Diene Monomer (EPDM) joints may be available to seal these horizontal joints that avoid possible acoustic leaks.

b) **Absorbent Porous Concrete Plate:** It should be made with porous concrete so that the thickness, relief and size of the gaps allow its acoustic performance to be guaranteed and that it will be maintained throughout the expected life of the acoustic screens. The characteristic resistance to compression at 28 days measured in a cylindrical specimen, must be equal to or greater than 1.25 MPa.The absorbent concrete layer should occupy practically the entire surface of the panel that is exposed to traffic, so that the absorbent area is distributed homogeneously. Porous concrete cannot be reinforced and its stability and cohesion must be guaranteed throughout the useful life of the screen.For the execution of the absorbent layer of porous concrete, different types of granular materials can be used (aggregates of different sizes, wood chips or chips, tire recycling pellets, etc.), either alone or in combination, which allows obtaining different degrees of acoustic absorption.

Modular panels have the double function of insulation and sound absorption **(Fig.5.6)**. Every manufacturer will design the shape and dimensions of each of these elements. The design and geometric characteristics of the modular panels may vary depending on the manufacturer, with thicknesses between 80 mm to 120 mm for the structural concrete part and between 80 mm and 200 mm for the sound absorbing coating; panel heights between 500 mm and 2,500 mm and lengths up to 6,000 mm depending on the inter-distance between posts of the support structure. The structural calculation of these elements for moderately aggressive environments and 50 years of mechanical useful life marks the use of minimum thicknesses of 120 mm on screens of 6,000 mm of inter-distance between posts, 100 mm on screens of up to 5,000 mm of inter-distance between posts and 80 mm in screens of up to 4,000 mm inter-distance between posts. Structural panel thicknesses of less than 80 mm should be avoided to ensure better compliance with sound insulation requirements.

Fig. 5.5 Representation of a Dense and Porous Concrete Noise Barrier

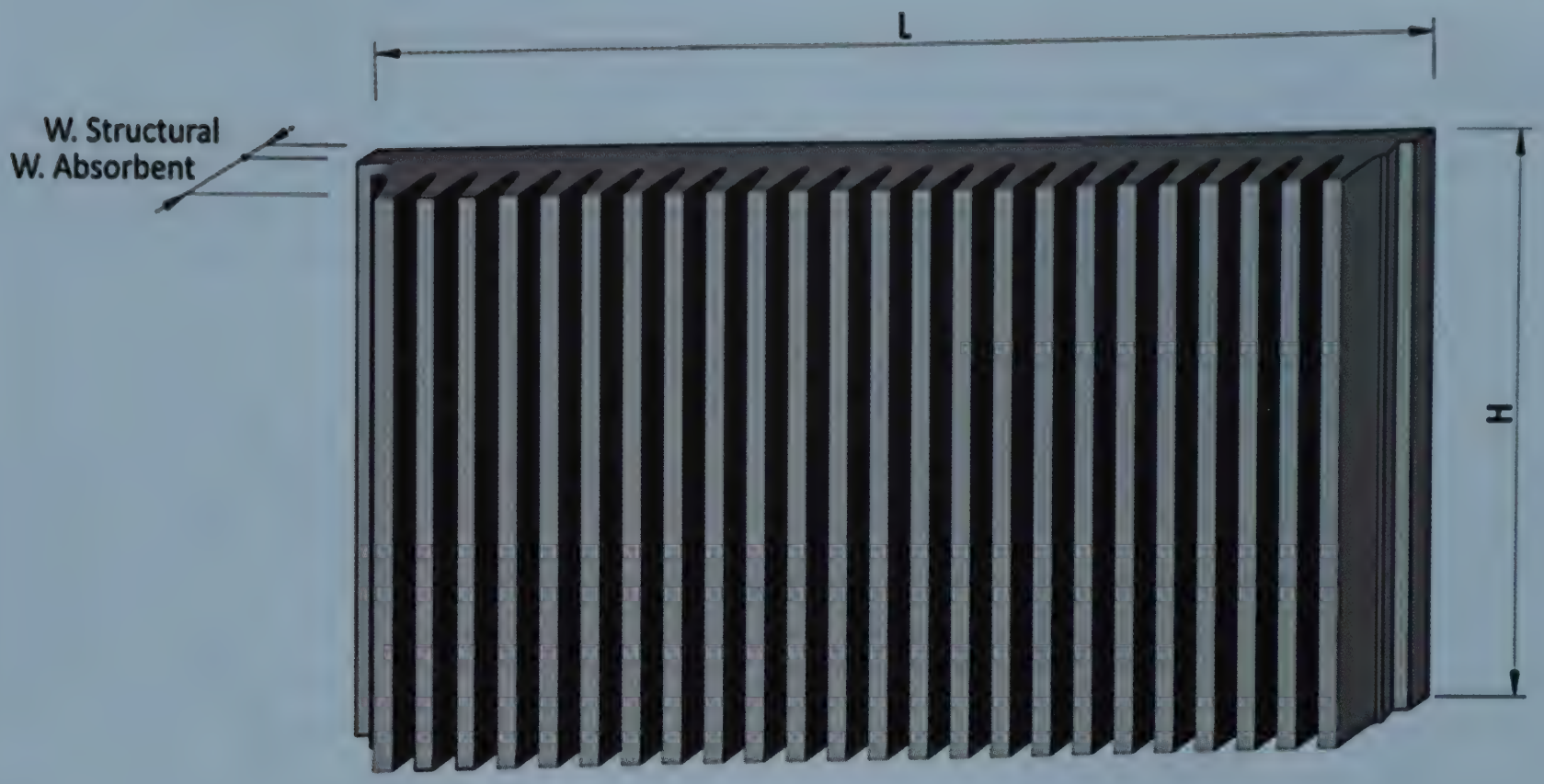


Fig. 5.6 Modular Concrete Panel

5.1.2 *Refelctive noise barriers*

Reflective noise barriers are unidimensional in nature and isolate the sound from the protected receptor by reflecting it back towards the source. They are useful when there are no receptors present in the opposite side of the barrier. They are also transparent and can be used in conjunction with Absorbing Panels to get desired efficiency while avoiding tunnelling effects.

The various kinds of reflective noise barriers are as follows:

- Poly Methyl Meta Acrylate (PMMA) Reflective Barrier
- Poly Carbonate Sheets Reflective Barrier
- Dense Concrete wall Reflective Barriers
- Metal Sheet Reflective Barriers
- Concrete Hollow Block Barriers
- Glass Barriers

5.1.2.1 Poly Methyl Meta Acrylate (PMMA) reflective barriers

These are reflective panels of extruded colourless or tinted PMMA sheets, which are supported by a galvanized powder coated metal and are attached with use of rubber gaskets having appropriate weathering capabilities with a lifespan of 15-20 years. They are very useful to provide transparency and for usage in conjunction with absorbing panels as PMMA allow more than 92% of the light to pass through. They also have high UV resistance and structural strength. PMMA mimics most of the properties of glass while being much more durable and half the weight.

They can also be used individually when no receptors are present at the opposite end or when a barrier is placed at both opposite ends. These barriers are useful in places where more light/ transparency is required. Due to their ability of light transmission, these barriers are preferred

over metallic barriers in locations such as at horizontal curves where the driver must be aware of his/her surroundings in order to reduce risk of accidents.

It may be cost effective to reduce the effects of reflected noise in certain cases by tilting the barrier away from the noise source by 10° to 15°. These barriers are given certain shapes to reduce the diffraction of sound which takes place at edges. The spacing of the columns, height and length of the panels shall be as per design approved by Structural Engineer.

5.1.2.2 Polycarbonate reflective barrier

Polycarbonate Noise Barriers are similar to PMMA Noise Barriers with some differences in phyical properties. Polycarbonate has a light transmission of around 80-90% for incident light depending on the thickness of the material, in comparison to PMMA Panels. Polycarbonate Panels have much less resistance to weathering as they lose colour much quicker than PMMA Panels and also have lower scratch resistance thus have a shorter life cycle in comparison. They have a high impact resistance around 30% more than toughened glass and thus preferred sometimes when such resistance is desired.

The installation of Polycarbonate Barriers is similar to PMMA Panels with the use of suitable frames and gaskets. Direct bolting of PMMA or Polycarbonate sheets is to be avoided wherever possible. The spacing of the columns, height and length of the panels would be as per design approved by Structural Engineer. A typical configuration of Polycarbonate/PMMA Panel with steel frames is given in **Figs.5.7** and **5.8.**

Fig. 5.7 Typical Framing of a PMMA/Polycarbonate Panel

RUBEER GASKETS
PERFORMANCE IMPROVEMENT
The bond between ths Steel Z Shaped Frame and the PMMA/ Polycarbonate is improved by placement of an EPDM Gasket between the Panel and Frame allowing the Panel Dilations.
This also improves the acounstic performance of the Panel by preventing any sound leakages.
EPDM
Gaskets

Fig. 5.8 Typical installation of a PMMA/Polycarbonate Panel

5.1.2.3 Dense concrete wall reflective barrier

Dense concrete is made from aggregates with a high density between 2,080 and 4,485 kilograms per cubic meter. Some of the high-density aggregates used are, barite, ferrophosphorus, limonite, hematite, ilmenite, magnetite, goethite, steel punching, and steel shots. These aggregates are much less porous, and the resulting concrete has a higher mass-to-volume ratio. Higher the density of the concrete, higher is the insulation value of the barrier. Dense Concrete Barriers usually comprise of concrete of 40 MPa or more and have a high wind load bearing capacity. Around 40 dB (A) of Insulation can be achieved for every 100 mm of width.

5.1.2.4 Metal sheet reflective barrier

Metal Sheeting Panels are used as Noise Barrier Panels to provide flexibility in barrier designs while facing obstacles at site. The barriers are purely reflective in nature and can be of two types:

- Steel Sheeting Barriers.
- Aluminium Steel Sheeting Barriers.

a) Steel Barriers

Reflective Steel Barriers comprising of Mild Steel of Structural Steel Grade are attached on to a metallic frame and then bolted onto a supporting column. The steel sheets are galvanized and then powder coated to improve weather resistance. Steel sheet of 0.9 mm is known to isolate around 22 dB of sound.

b) Aluminium Barriers

Reflective Aluminium Barriers of Alloy Grade Aluminium having high tensile strength may be used to reduce the weight of the barrier, they are similarly attached to a frame and then attached to a supporting column with bolts. The barriers are preferred in areas with extreme low temperatures as steel tends to become brittle at extreme temperatures. An Alloy Aluminium Sheet of 1.6 mm is known to isolate around 23 dB. The initial cost of the panels is much higher than steel and are considered as per site conditions justifying their use **(Figs.5.9 and 5.10)**

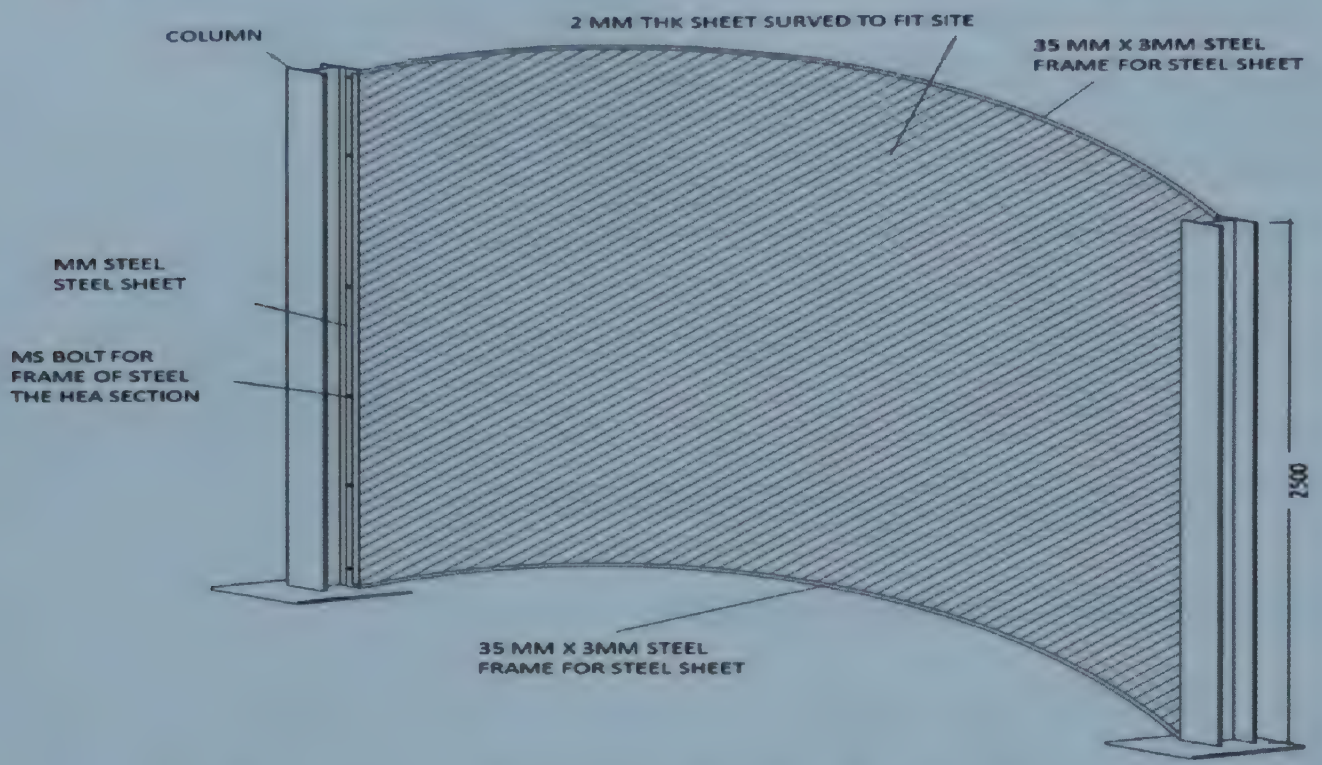


Fig. 5.9 Cross-Section of Metallic Sheeting Panel

Fig. 5.10 Reflective Panel Usage to Accommodate Fix Objects

5.1.2.5 Concrete hollow block barriers

Walls made of Masonry Concrete Hollow Blocks filled with soil or various composite material stacked on top of each other and then plastered from one side act as good sound reflective barriers. Depending on the kind of design and material used for filling of the blocks, the barriers can have a sound isolation as much as 30 dB to 60 dB.

The Sound Waves interact with the surface of the barrier and some of them get reflected back and the other enter the hollow blocks due to their porous nature which get absorbed by the soil or composite material filled inside the block. Very little noise gets transmitted due to reflection and absorption. As not much data is available on the absorption levels of such a barrier, the Concrete Barrier is treated as a reflective type of barrier. However, if ample absorption levels are displayed via testing/ test reports, then the same may be considered as an absorbing panel as well.

One of the commonly used concrete hollow block has dimensions of 240 mm x115 mm x90 mm with 3.8-4.4 kg in weight and having 1680-1780kg/m^3 as average density with a double row of rectangular or semi-circular holes. The opening of the holes is only on one side and the other side is usually plain. The blocks are stacked on top of each other and plastered with mortar on the receptor side. To evade the effect of atmospheric weathering and to provide pleasant aesthetics, the walls can be painted in various colours and patterns. Picture of common designs of hollow concrete blocks is given in **Fig.5.11**.

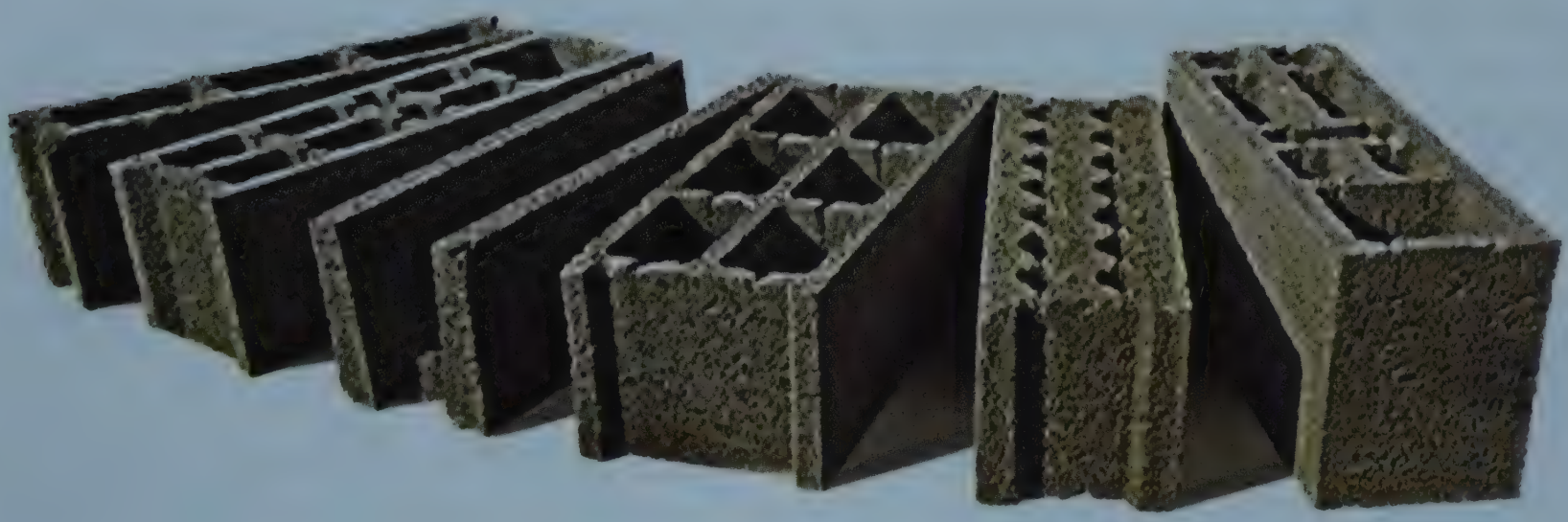


Fig. 5.11 Typical Concrete Hollow Blocks

Another useful design is the use of interlocking blocks in a step type formation and filling the hollow blocks with soil implanted with flowering or other plants. This kind of formation not only provides an interesting aesthetic appeal to the barrier but also provides good acoustic properties due to the various angles provided by the reflective surface. An example of such design is shown in **Fig.5.12.**

Fig. 5.12 Step Type Concrete Block Barrier with Plantation

5.1.2.6 Glass noise barriers

Barrier Panels made of tampered and laminated glass can also be used as a reflective noise barrier. Different sheets of the laminated glass noise barrier panels shall be bonded together by Poly Vinyl Butyral (PVB) interlayers or similar material with minimum thickness 1.52 mm.

These panels are transparent in nature and have a light transmission of 85 percent for a clear panel. A 6 mm Toughened Glass Sheet can isolate noise by around 22 dB.

The breaking strength for tampered and laminated glass is usually least. It's 95 N/mm^2 to 65 N/mm^2 for a laminated heat strengthened glass and 40 N/mm^2 for a laminated float glass. These panels are usually more fragile and have very little impact resistance thus requiring regular maintenance, thus Poly Carbonate/PMMA is preferred for Road Side Installations.

When road side availability of land is less and no space is available, it may be considered to install doors and windows of such Glass Panels to provide Acoustic Insulation to the receptors.

5.1.3 *Natural barriers*

Noise Abatement can also be achieved by using various natural resources like earth mounds, hedges and plantations, rock filled gabion cages etc. especially, if the sound reduction desired is not very high and adequate land is available to construct a natural barrier.

Natural Barriers are of the following types:

- Earth Berms or Earth Mounds
- Gabion Walls
- Green belt

Plantation based Natural Barriers and Wood Based Natural Barriers are also prevalent worldwide. Their successful design and implementation depend on the natural surroundings and environment of the location where they are being installed.

5.1.3.1 Earth berms or earth mounds

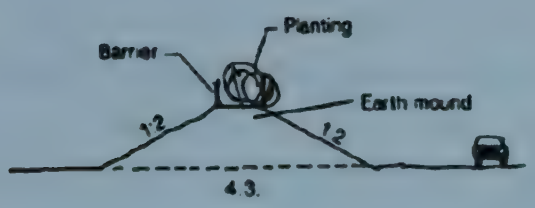
A mound is made up of Earthen Material like sand, stone, gravel and soil with or without vetation growing on it, similar to what is naturally found in hills is one of the most effective Noise Barriers especially in rural or Protected/ wildlife / forest areas where adequate land may be available.

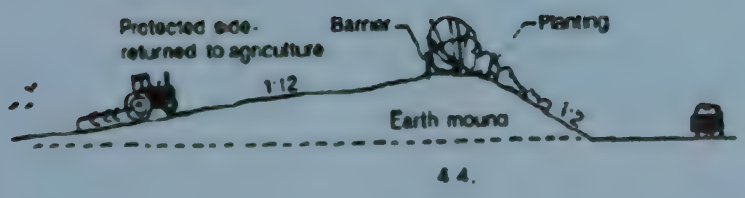
When the sound waves interact with the earth mound, some waves are absorbed and some are reflected back thus protecting the receptor. An earth mound to be used as a noise barrier is typically 3 m in height with a slope of 1 in 2 and a width of 13 m. The slope of the earthen mound can be 1 in 6 or less on the protected side as it increases the stability of the mound and will result in reducing visual effect. The mound length does not have considerable effect in reducing the noise levels but it should be sufficient enough to protect the receptor. When the land area is restricted, one can cut the sloping edge along the road and place a wall made of either timber or concrete for support. Timber being natural material is preferred. However, it is less durable compared to concrete walls.

Mounds are divided into four categories based on height, they are Small-Height Mounds (0-2 m), Mid-Height Mounds (2.5-3 m), Tall-Height Mounds (3.5-4.5 m), and Very Tall Height Mounds (>4.5 m). Based on the situation, different heights are adopted. For comparison of earth berm effective heights refer to **Fig. 5.14.**

Plantation is encouraged on top of mounds. Different types of vegetation help in reducing the visual intrusion. One can also do farming and cultivate useful plants along the protected side of the mound.Slope shall be such that allows penetration of rain water that falls on the mounds. There is need to ensure that sufficient water is retained in mound so that plants will be alive during summer. Drains should be provided at the top of the sloping side, as the water will overflow on roads during rains.

Earth Mounds are also useful as a cost-effective method when a very tall Man-Made Noise Barrier is required and the Earth mound can be used as the base for the barrier while not compromising on the Noise Reduction **(Figs.5.13 and 5.14).**





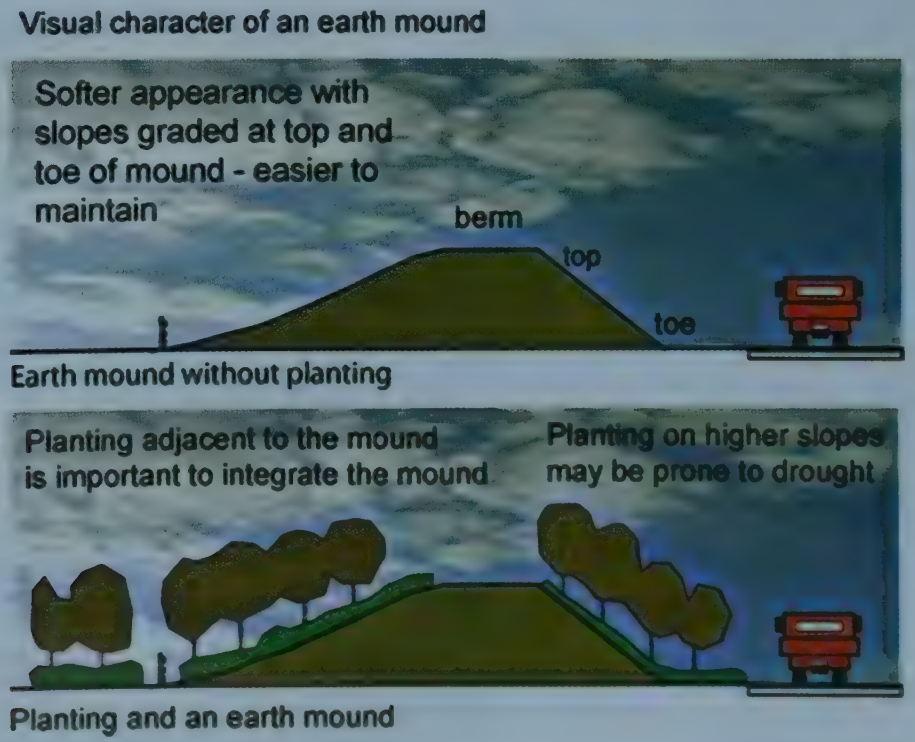
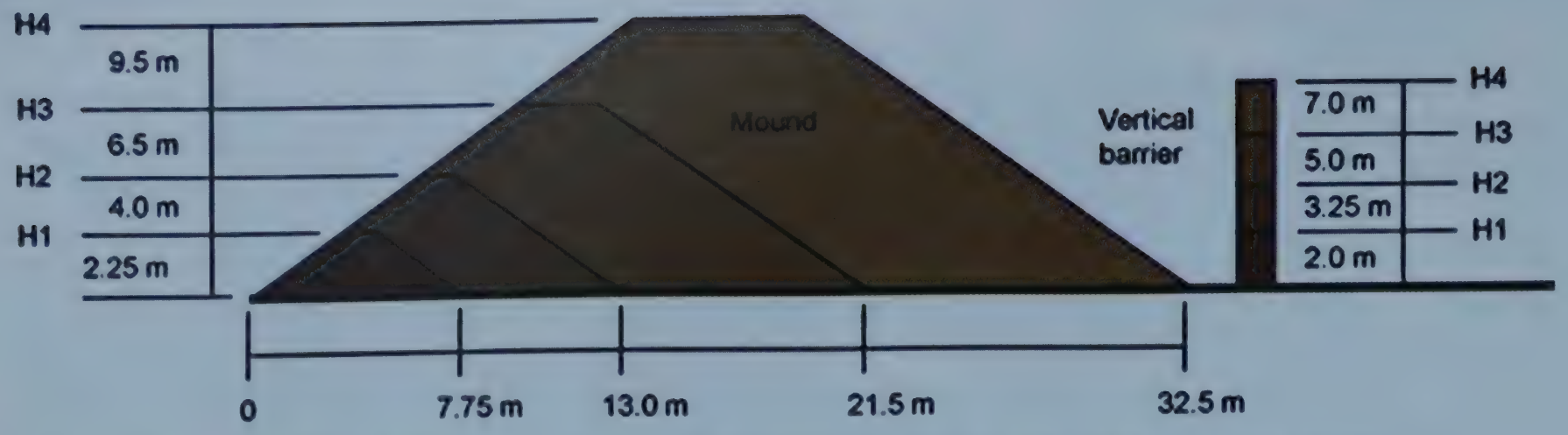

Visual character of an earth mound
Softer appearance with slopes graded at top and toe of mound - easier to maintain
berm
top
toe
Earth mound without planting
Planting adjacent to the mound is important to integrate the mound
Planting on higher slopes may be prone to drought
Planting and an earth mound

Fig. 5.13 Earth Berms as Effective Noise Barriers



Comparison of heights in metres

	H1	H2	H3	H4
Vertical barrier	2.0	3.25	5.0	7.0
Mound	2.25	4.0	6.0	9.5

NOTE: The dimensions will vary as berm widths and slope angles depend on the structural stability of different soils and fill materials

Not to scale

Fig. 5.14 Mound/Vertical Barrier Height Comparison

(Source-Roads and Traffic Authority of New South Wales, Australia)

5.1.3.2 Gabion walls

Gabion Noise Barriers consist of Galvanized Steel Wire Gabion (sometimes PVC coating is applied to wires for extended lifecycles) cages tightly filled with rock of high density. The rock filling is done in such a manner that very little gaps are left for sound to pass through.

The barrier usually needs to be quite wide and quite tall to be effective and it is noticed that a 1 m wide Gabion Structure with sufficient height can isolate sound up to 60 dB. Gabion walls can be designed in various forms to blend with the natural aesthetics of the place they are being installed.

When receptors are present in small area on a rural section of the highway and the road geometry is such that a long length of barrier is required for the barrier to be effective, the approach and departure side of the barrier could be constructed with gabion walls and a transparent PMMA or Poly-Carbonate Barrier or as considered appropriate could be placed directly in front of the receptor. A typical Gabion Installation is given in **Fig.5.15.**

Fig. 5.15 Angular Shaped Gabion Noise Barrier

5.1.3.3 Green belt

For vegetation to provide a substantial, or even noticeable, noise reduction, the vegetation area must be at least 5 m in height and 30 m wide and dense enough to completely obstruct the line of sight between the source and the receiver. This size of vegetation area may provide up to 5 dB(A) of noise reduction. Taller, wider and denser areas of vegetation may provide even greater noise reduction. Native species shall be planted.IRC:SP:21 on "Guidelines on Landscaping and Tree Plantation" or any other latest directions or guidelines by MORTH/ IRC shall be referred. However, application of vegetation screen as noise barrier is constrained due to scarcity of land (Mengeet. al., 1998 & FHWA, 2017 & ISO, 1993). Vegetation screen can also be used in conjunction with other noise reduction techniques and for aesthetic enhancement (FHWA,1974). The presence of vegetation on an earth mound provides more effective screen than either the mound or the vegetation alone. Consequently, the role of vegetation is limited to enhance the performance of earthworks or to quieten open countryside where a substantial reduction in noise is not required. A horticulture expert should be consulted for proper design and implementation of such barriers.

5.2 Material Properties and Specifications

5.2.1 *Transmission loss of noise barrier materials*

All materials permit sound energy to pass through, although in varying degrees depending on the material and the frequency of sound. The attenuation of sound passing through a material is referred to as Transmission Loss (TL).

For a barrier to be fully effective, the amount of sound energy passing through it must be significantly less than that passing over the top (or around the edge). When noise levels of two sources L_A and L_B are added, if difference between them is larger than 10 dB, addition result will be less than 0.5 dB to the higher level.

For Example: L_A = 80 dB and L_B = 70 dB; L_{A+B} = 80.4 dB

Thus, if the portion of sound transmitted through the barrier is 10 dB lower than that which goes over the barrier, the overall sound received is essentially determined by the energy travelling over the barrier. For acoustical purposes, any material may be used for a barrier between a noise source and a noise receiver as long as it has a TL of atleast 10 dB (A) greater than the desired noise reduction (i.e., Insertion Loss (IL) determined in the EIA studies). For example, if a noise barrier is designed to reduce the noise level at a receiver by 8 dB (A), the TL of the barrier must be at least 18 dB (A). The transmitted noise may then be ignored, because the diffracted noise is at least 10 dB (A) greater and hence the noise propagation path must be over the barrier. **Table 5.1** gives approximate TL values for some common materials, tested for typical A-weighted traffic noise frequency spectra that can be roughly referred while choosing barrier material type. In terms of noise reduction, the maximum value that can be achieved theoretically is 20 dB (A) for thin screens (walls) and 23 dB (A) for berms (ET 03.305.010.5, 2020)[4] .

[4]Technical Specification Acoustic Screens1st Edition: March 2020.

Table 5.1 Approximate TL Values for Various Noise Barrier Materials (FHWA, 2017)

Material	Thickness (mm)	Surface Density (kg/sqm)	Transmission Loss* (TL) in dB(A)
Polycarbonate	8-12 **	10 – 14	30 – 33
Acrylic [Poly-Methyl-Meta-Acrylate (PMMA)]	15	18	32
Concrete Block (200 mm x 200 mm x 405 (8"x8"x16") light weight	200	151	34
Dense concrete	100	244	40
Light concrete	150	244	39
Light concrete	100	161	36
Steel, 18 ga	1.27	10	25
Steel, 20 ga	0.95	7.3	22
Steel, 22 ga	0.79	6.1	20
Steel, 24 ga	0.64	4.9	18
Aluminum Sheet	1.59	4.4	23
Aluminum Sheet	3.18	8.8	25
Aluminum Sheet	6.35	17.1	27
Wood, Fir	25	16.1	21
Wood, Fir	12	8.3	18
Wood, Fir	50	32.7	24
Plywood	12	8.3	20
Plywood	25	16.1	23
Commercially available Absorptive panels with mineral wool backed by metal sheet***	80 – 125	20 – 30	20 – 30#
Plexiglass	6	7.3	22

*Values assuming no opening or gaps in the barrier

**Industry experience has shown that for any noise barrier having a thickness of less than 12 mm the resonance created due to the passing vehicles negates the sound attenuation attributed to the barrier.

*** Industry Collated Data from Indian Manufacturer Websites.

The data on commercially available Absorptive barriers is in dB and not dB(A). The difference between dB and dB(A) in the frequency range audible to humans is low.

Note:

This table is for representative purposes, and the values of acoustic properties obtained during testing and certified in test reports should be considered while designing and finalization of barrier before installation. This is not a comprehensive list and other materials and designs may be used with values for the same taken from certified acoustic test reports.

5.2.2 *Acoustic and non-acoustic specifications of noise barriers*

The Acoustic and Non –Acoustic Specifications applicable to construction and installation of Absorbing and/or Reflecting Noise Barriers for roads are given in **Tables 5.2 and 5.3.**

Table 5.2 Acoustic Performance Criteria

S.No	Parameter	Specifications/Description
1.	Maximum height of barriers above-finished road level	• Six meters (Any additional height required to achieve the performance required is to be approved by the Client's engineer, all heights proposed need to be backed by a Structural Stability Report).
2.	Minimum mass of barrier per Surface area	• 15 kg/m² for transparent panels and metallic panels. • Easy to remove and reinstate by maintenance
3.	Sound Absorption- Minimum material single-number rating DL_{α} or $DL_{\alpha NRD}$: (in accordance with EN1793-1)	• 0 dB for transparent panels, • Metallic Panels • Mono Absorbent- 20 dB • Bi Absorbent- 20 dB • 4 dB for Absorbing Concrete Panels
4.	Minimum air-borne sound insulation DL_R:(in accordance with EN1793-2)	• 26 dB for transparent panels * • 26 dB for metallic panels * • 36 dB for Reflective Concrete Panels*
5.	Minimum in situ single number ratings of air borne sound insulation under direct sound field conditions $DL_{SI,\ G}$ (in accordance with EN1793-6) **	• $DL_{SI,G}$ minimum 30 dB for transparent panels, metallic panels and concrete panels*
6.	Minimum in situ single number ratings of air borne sound reflection under direct sound field conditions DL_{RI} (in accordance with EN1793-5) **	• DL_{RI} minimum 7 dB in the elements for metallic panels* • DL_{RI} minimum 4 dB for Absorbing Concrete Panels*

*The test specimen shall be mounted in the test opening and assembled in the same manner as the manufactured device is used in practice with the same connections and seals between component parts.Test reports will not be valid if the sealing system between the panel and the post and the horizontal joints between panels is not clearly specified. Joint fillers should have permanently insulating properties.

** EN-1793-5 and EN-1793-6 have been added in addition to EN-1793-1 and EN-1793-2 to showcase real world performance of a barrier. For detailed explanations, refer to the guidelines.

Table 5.3 Non-Acoustic Requirements

Parameter	Requirement
Design wind load (test load=1.5 times design wind load of area of installation), (in accordance with EN1794-1)	Standard requirement as per EN1794-1 Annex A, with until 2 m span in transparent panels and until 5 m span in metallic panels, with not less than a design wind load of 150 kg/m² (225kg/m² test wind load) through a real test, no calculations are allowed. In case the project specifications mention a lower or higher wind load then the same would be applicable, if no specifications are given then the above minimum limit shall be applicable. Span Lengths tested to meet wind loads as per design wind loads of the project shall be applicable.
Design snow load* (test load=1,5x designs snow load), (in accordance with EN1794-1) *Only Applicable in Areas with Heavy Snowfall	Standard requirement as per EN1794-1 Annex E, with until 2 m span in transparent panels and until 5 m span in metallic panels, with not less than a designs snow load of 15 kN/2x2 (22.5kN/2x2 tests now load). In case the project specifications mention a lower or higher snow load then the same would be applicable, if no specifications are given then the above minimum limit shall be applicable. Span Lengths tested to meet snow loads as per design wind loads of the project shall be applicable.
Self-Weight	Standard requirement as per EN1794-1, Annex B requiring:evidence through real test that no part of the acoustic elements, sealants, supporting structure or base structure shall be subject to lasting deformation as a result of the load exerted by the overlying units for the maximum height of the noise barrier, whereby 1.3 times the load of the dead wet weight.
Impact of stones	Standard requirement as per EN1794-1, Annex C. Test result must be satisfactory.
Resistance to fire	Required as per EN1794-3, Annex A: Class 3 for both transparent and metallic panels.
Danger of falling debris including anti- detachment	Required as per EN1794-2, Annex B:Class 2 or 3 for transparent panels/ metallic panels on bridges and embankments. Keeping in mind the site-specific safety requirements the Engineer in-Charge may specify Class 3 for the specific project.
Light reflection	Required as per EN1794-2, Annex E: with not less than Class1 for transparent panels and Class 2 for metallic panels This parameter does not apply to concrete acoustic screens.
Transparency	Required as per EN1794-2, Annex F, with a transparency not less than 80 percent per transparent panels. No requirements for metallic panels.

Use of Noise Barrier in combination with other traffic furniture/barriers.	1. Installation on top of Concrete Crash Barrier is permissible. 2. It is to be noted that a noise barrier cannot act as a crash barrier under normal circumstances, unless the system has been specifically tested for the combined use - i.e., as a Crash Barrier (as per guidelines in IRC:119) and a Noise Barrier (as per this code). 3. Concrete Noise Barriers do not necessarily act as safety barriers unless they are specifically designed/ tested as safety barriers. 4. It shall also be acceptable to integrate the road lighting system within the same supporting structure of the acoustic barriers.
Safety and Maintenance	1. The Noise Barrier shall be constructed in removable structural modules to allow for easier and cost-effective maintenance 2. Transparent Panels Inclusive of embedded stainless-steel cable retaining structure for sliver retention and restrain fragment due to breakage is permitted if required as per site conditions. 3. No Direct Bolting of Transparent Panels will be allowed to prevent tearing under wind load.

6. INSTALLATION

The installation of a Noise Barrier plays an integral part in its performance as much as the material used in the Noise Barrier. It is also important to note that installation of a noise barrier depends highly on its structural criteria considered.

The Noise Barrier shall be installed as per the manufacturer's specifications at locations identified in the contract or identified by the Engineer-in-Charge.

The Noise Barrier shall be constructed in a modular manner and shall be done so that no gaps exist after construction. If there is a difference in level due to site conditions, adequate amount of sealing, plumbing or leveling is to be done of Noise Barrier as per Manufacturer's Specifications to ensure proper sealing of the Acoustic Wall being created.

6.1 Structural Considerations

Structural considerations are equally important for the safety and durability of the noise barrier. As noise barriers are high, do not have gaps, and have a length of typically more than 50 m, they become like a wall/obstruction for wind. Thus, the structural design of the noise barrier should be tested to withstand wind load for the appropriate wind speed (as per the location).

The barrier must meet the Mechanical performance and stability requirements as per EN-1794-1 for the following clauses:

- Clause no. 5.2 Wind Load and Load Due to Passing Vehicles
- Clause no. 5.3 Self Weight
- Clause no. 5.4 Impact of Stones
- Clause no. 5.5 Safety in Collisions (Manufacture must declare if barrier is tested as per EN-1317-2 or not)
- Clause no. 5.6 Dynamic Load Due to Snow Clearance (This clause shall only be applicable if system is being installed in an area with heavy snowfall)

The Manufacturer shall provide all relevant reports/certificates from an Indian or International Accredited Testing Laboratory having requisite accreditation to conduct test as per various European, Indian and other International codes mentioned in these guideline.

6.2 Site Preparation

The installation of a Noise Barrier imparts a substantial amount of load at the installation location not only due to the dead weight of the noise barrier but also due to Wind Load factor caused by erection of such a barrier.

The Site for Installation must be adequately prepared with proper compaction in case of on ground installations and properly designed parapets in-case of installation on structures.

Due consideration should be given for viability of the installation location at the time of preparing the contract.The installation of noise barrier should be carried out in such a manner that no gaps are present between the barrier panels or beneath the bottom panels after completion of the barrier installation.

Owing to the immense variations possible in the locations for installation of a Noise Barrier, an opinion must be sought from a Structural Consultant for the Structural Stability of the Installation Methodology and this should be included in the contract. The Structural Consultant shall provide a viability report verifying the Contractor's Installation Designs. The Engineer In-Charge or his appointed domain expert is to determine and verify the suitability of the Installation Location for additional load of the Noise Barrier.

For Natural Barriers, the design must withstand deterioration due to Environmental Factors along with Structural Stability of such a barrier.

6.3 Footings/Fastener Attachments

All footings/fasteners for the noise barrier panels shall be as per the manufacturer's design approved by the Structural Consultant for Structural Stability in compliance with latest relevant Indian or International norms.

6.3.1 *Installation on ground (except for earthen berms and vegetation):*

All footings for the noise barrier panels shall be as per the Manufacturer's design approved by the Structural Consultant for Structural Stability in compliance with latest relevant Indian or International norms.

While designing the footings for installation of the Noise Barrier, the Designer must factor in not only the Dead Weight of the Noise Barrier but also the Wind Load Factor as per the design wind load of the area of Installation.

In-case of Post and Panel type of Noise Barrier, the footing shall be of shape and size as per Installation Design and shall be constructed with minimum M-30 Grade Concrete with suitable reinforcements.

Base units adjacent to fill, soils, granular material and organic soils shall always be made of concrete.

6.3.2 *Installation on concrete surfaces*

Installation on Concrete Surfaces shall be done using suitable Chemical/ Mechanical Fasteners. The installer must submit Structural Analysis and Design Software Calculations to show the Structural Stability of the Installation in combination of the said fasteners.

Joint fillers (sealing strips) could be inserted between the concrete base and the lower side of the first panel in order to compensate for irregularities in the base and changes in the volume of the units due to alterations in environmental conditions (changes in temperature or humidity).

6.3.3 *Installation on bridge parapets or boundary walls*

While installing on a Parapet or a Boundary Wall, the Engineer-in-Charge should predetermine the feasibility of the Parapet/Boundary Wall to withstand the additional load of the Noise Barrier.

The Installation of the barrier shall be done using a specifically designed Base Plate and suitable Mechanical/Chemical Fasteners and the feasibility of such design should be verified by the Structural Consultant.

6.4 Posts

All Posts and Steel Elements used for Noise Barrier shall be of Structural Steel, Hot Dip Galvanized as per requisite IS and MoRTH Specifications. The Posts can either be used in galvanized finish or may further be Powder Coated/Epoxy Painted in appropriate colours in accordance with Site Specific Design of the Noise Barrier.

The top of footing and underside of post base plate shall be filled with non-shrink grout according to the Manufacturer's Specifications.Precast noise or crash barrier units or both shall be positioned to have complete contact with the post flange along the traffic side of the units.

Tolerance for post plumb shall be according to the manufacturer's specifications.

Joint fillers must be inserted in the gap between the panels and the flange interior surfaces of the posts just in case the laboratory test was made with those joint fillers.

6.5 Panels

The design of the panels is modular, generally of same height and width. The various kinds of panels are used either individually or in combination with each other as per site requirements. Panels of typical spans from 0.5 m to 6 m (smaller panels may be required as per site conditions to fill gaps) shall be installed horizontally and stepped when necessary to match the elevation profile specified on the Working Drawings. Changes in horizontal direction shall be made using special arrangements of the posts according to the Manufacturer's Specifications. All panels shall be cleaned of any oil, dirt, and debris

6.6 Noise Barrier on Structures

Noise Barrier shall be attached to the structure as per the Structural Consultants verified design. Adequate measures and precautions shall be taken to ensure that the water does not pond on the structures due to the installation of the Noise Barriers.

In case the installation of the Noise Barrier demands removal of Hand Rail from the structure, the same may be incorporated in the Noise Barrier Design at the design Stage of the barrier by attaching the hand rail to the posts of the Noise Barrier. Such hand rail installation should be done in a manner that it does not affect the structural stability of the Noise Barrier and should be done before Galvanizing and Painting of the Posts.

An example of one such installation is given in **Fig.6.1**

Structures refer to typical roadside structures like, Major and Minor Bridges, Pedestrian Underpass, Cattle Underpass, Vehicle Underpass etc.

Fig. 6.1 Example of Handrail provided attached to Noise Barrier Structure

6.7 Noise Barriers and Crash Barriers (Vehicle Restraint Systems)

The Noise Barrier shall not be combined with the Crash Barrier or Vehicle Restraint System as it affects the performance of the Crash Barrier System during a Crash. The Noise Barrier must always be installed separately behind the Crash Barrier.

In case enough space is not available to install Noise Barrier behind the Crash Barrier and it will be installed combined with the Crash Barrier, then the same may be allowed if a real crash test or simulation has been run to show its performance as per desired performance level for MASH TL-4 or EN-1317 H1/H2 Containment Levels.

6.8 Underground Utilities and Drainage

Reduced Post Spacing shall be allowed as per manufacturer's specifications to avoid putting posts on top of Underground Utilities and Drainage.

6.9 Noise Barrier and Lighting Fixtures

If a tall Noise Barrier is required, the Noise Barrier can be combined with Lighting Fixtures as long as the same is done at the design stage and proper provisioning has been made for the same as per the Manufacturer's recommendations.

Such alterations in design should also be verified for structural stability so as not to adversely affect the stability of the Acoustic Wall being constructed.

6.10 Noise Barrier and Overhead High Voltage Lines

When the potential of arching exists due to the close proximity of existing overhead high voltage lines, steel noise barrier panels and posts shall be grounded in accordance with relevant norms related to high voltage electrical lines

6.11 Access for Inspection and Maintenance

At the time of installation of Noise Barrier, adequate care must be taken that easy access is available for Regular Inspection and Maintenance of the Noise Barrier.

Routine maintenance requirement can be minimized by self-cleaning provisions like transparent sections should be kept clear of splash zones, but will need cleaning regularly; and regular trimming of vegetation. Space should be allowed between planting and the face of a barrier sufficient to give access for maintenance. However, in some locations, there will be a need to consider restricting public access to the protected side to prevent vandalism.

Access for repair (and routine maintenance on the road user side) should normally be from the verge or road shoulder i.e., within road land. Unless space within the highway is severely restricted, there should be no need for frequent access to the protected side. But adjacent land owners should be restrained from incorporating a barrier into their property.

Any openings, frames, doors and hardware for noise barrier access shall be supplied and installed in accordance with the manufacturer's Working Drawings and installation instructions at the locations and of the types specified in the Contract Documents.

Openings if required shall be cut a minimum 1 m from centerline of post to centerline of the opening. Any opening for fire hoses shall be 1.3 m to 1.5 m measured from the finished ground level next to the noise barrier.

The standard openings for fire hoses and access doors are given in **Table 6.1.** Other openings if any, in the contract documents shall be as per the Manufacturer's Design and Contract specified dimensions and centered between two adjacent posts.

Table 6.1 Standard Openings

Noise Barrier Access Standard Opening Sizes Type of Door/Opening	Opening Size (W mm x H mm)
Fire Hose Access	254 mm x 254 mm
Person Door Access	915 mm x 2438 mm

Each noise barrier access opening shall be fitted with a hinged door that opens away from the roadway to a minimum opening angle of 110°.

When doors are in the closed position, there shall be no impact to the acoustical characteristics of the noise barrier system. All gaps between openings and frames shall be sealed to ensure that there are no gaps.

7. MAINTENANCE

7.1 Inspection

Periodic Inspection of the Installed Noise Barrier must be carried out to check for

- Any gaps that may have been formed over a period of time.
- Structural Damage to Panels due to Vehicular Crash/ wind load
- Stability of Foundations
- Any other damage due to forces of Nature such as damage to absorbing materials due to heavy rainfall.

7.2. Repairs and Replacement

7.2.1 *Foundations*

If any damage is noticed on the foundations of the Noise Barrier, the same must be repaired immediately. At the time of repairs, adequate measures must be taken to account for corrosion, formation of gaps etc. and if need be, replacement should be considered.

7.2.2 *Panels*

Post and panel kind of barriers are intrinsically modular in nature. It would be beneficial and cost effective to replace the panels, if their outer shells have suffered structural damage. In case, only the inner absorbing material has been damaged, the same may be replaced using the existing outer shell.

7.2.3 *Natural barriers*

Natural Barriers are also susceptible to damage over a period and periodic maintenance must be carried out to ensure their stability and proper functioning. Healthy and widespread vegetation on Earth Berms adds to not only their strength but also adds to the acoustic performance.

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